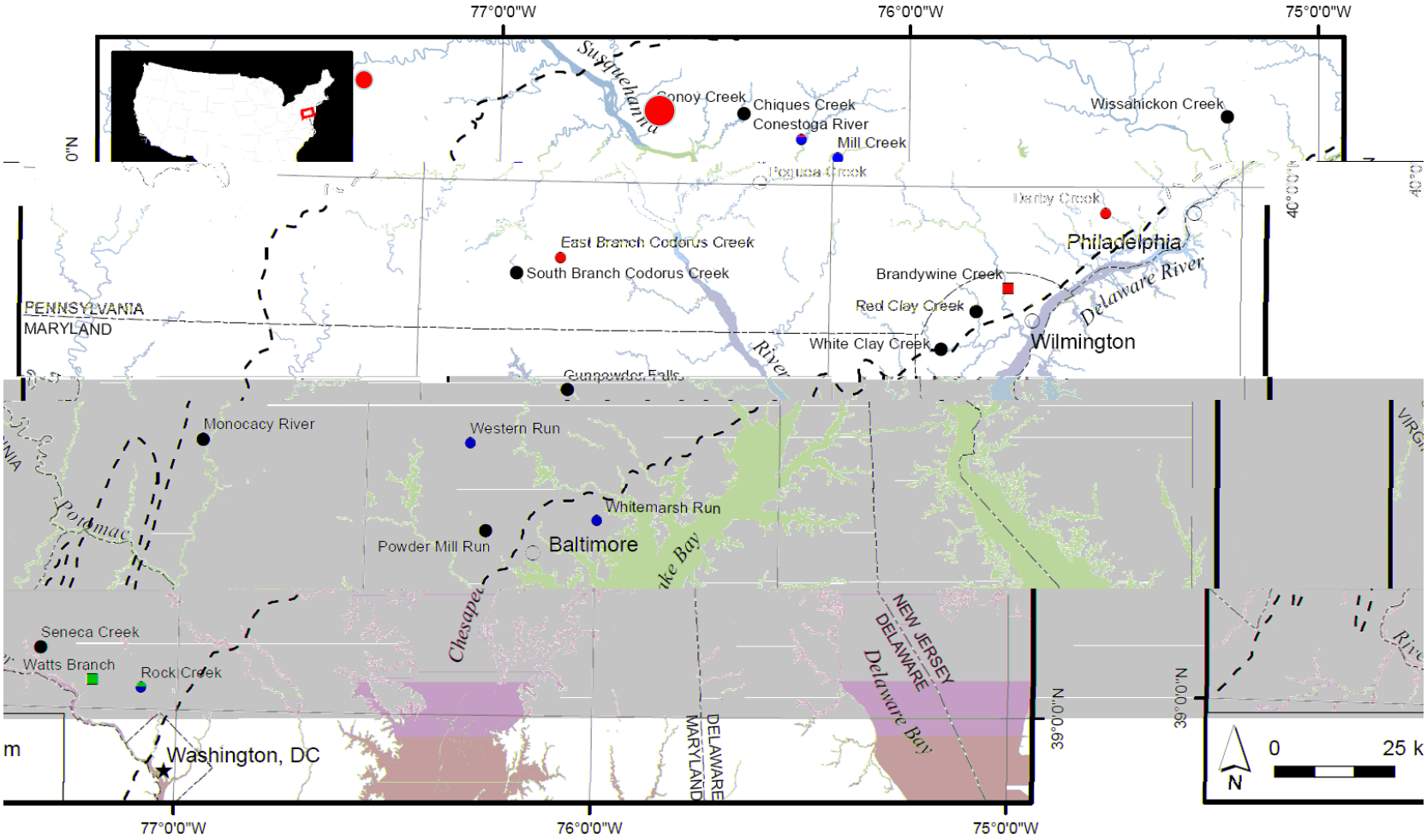
The Rise and Fall of Mid-Atlantic Streams: Buried Soils and the History of Valley Bottom Sedimentation and Erosion

Dorothy Merritts, Robert Walter, and Mike Rahnis (F&M College)

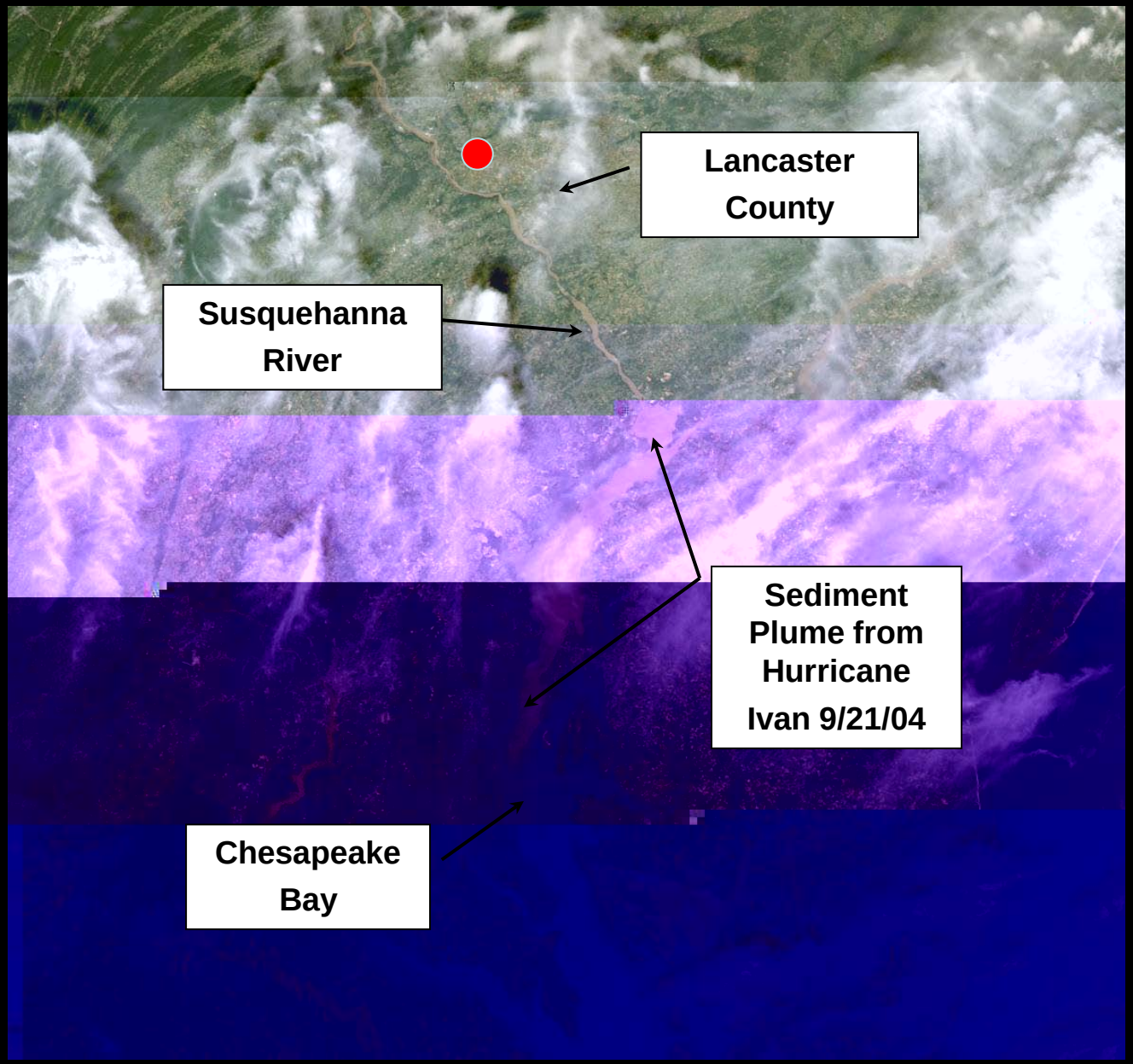


Study Region includes 21 Mid-Atlantic Watersheds

(Sites depicted in red have radiocarbon age control)

Soils and Sediment in the Chesapeake Bay Watershed

The conundrum of causality in environmental problems



What are possible sources (and causes) of sediment in the Bay?

What are possible sources (and causes) of sediment in the Bay?

Fields, farms, soil erosion from uplands? In the 1930s? In 2010?

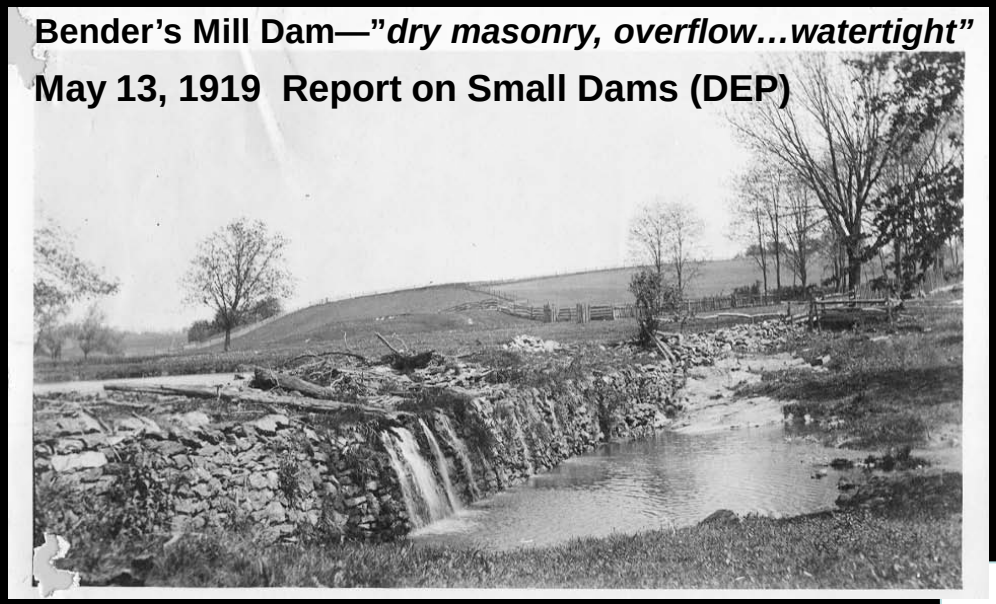
What are possible sources (and causes) of sediment in the Bay?

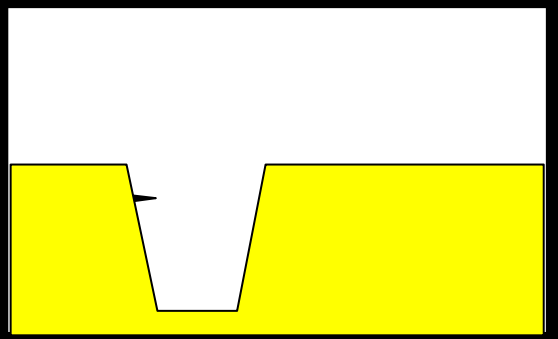
Soil erosion from cows trampling banks?
How do cows cause deep incision into fine-grained sediment?
How did the sediment get in the valley bottom?

What are possible sources (and causes) of sediment in the Bay?

Storm water runoff, rilling, and gullying.
What is the storm water cutting into? How much of this impact is due to water and how much to changes in base level (grade)?

What are possible sources (and causes) of sediment in the Bay?





A new source: Millponds

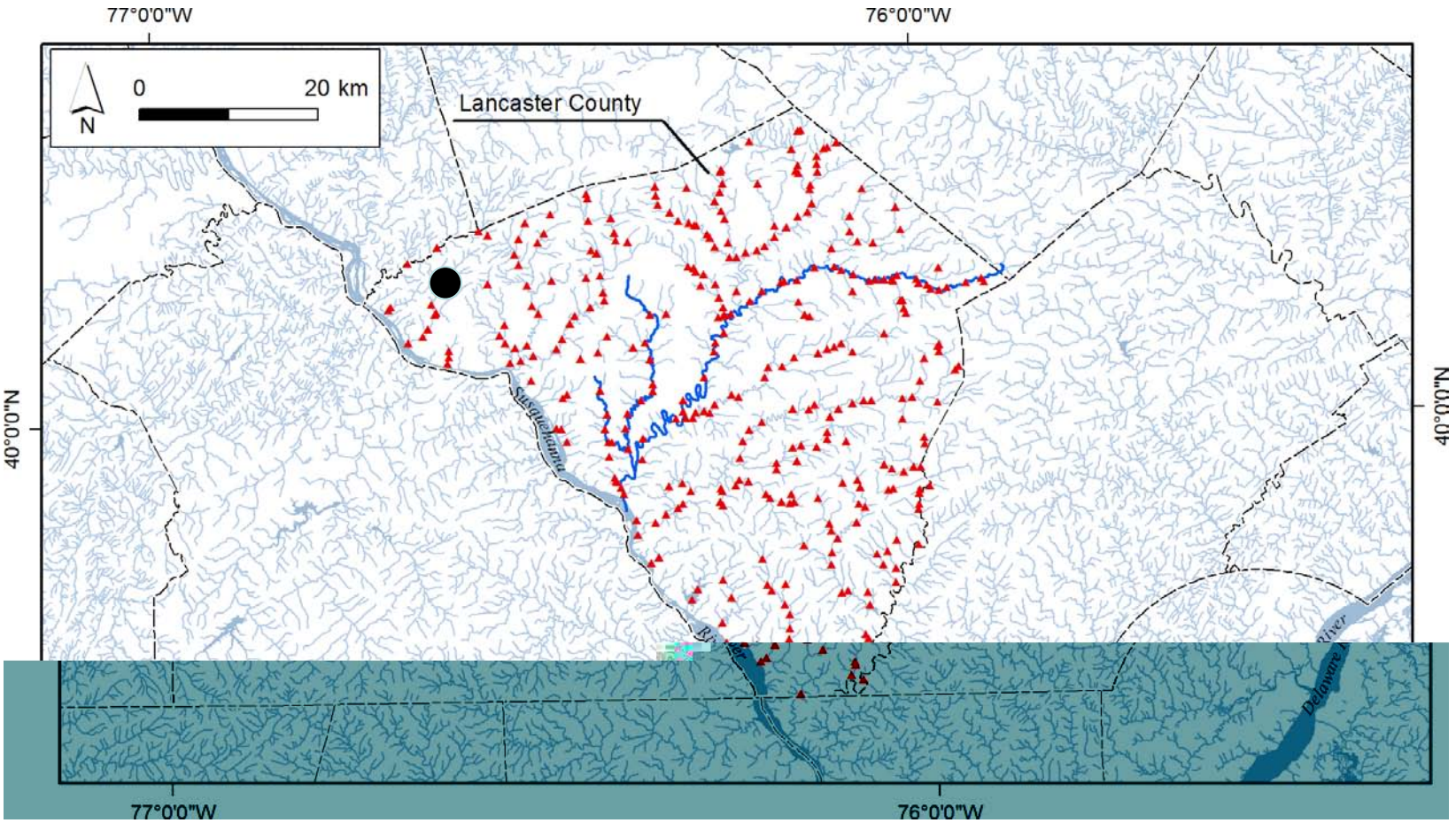
Historic sediment stored along valley bottoms (with help from breached dams, incised/straightened streams, and changes in grade).

150 m upstream of breach; seeds 7200 yrs BP at base

CLINTON, NEW JERSEY—THE RED MILL (1810)

A photogenic symbol of early America's rural industry….. originally a woolen mill. …. used at different times to process grains, plaster, talc and graphite, to generate electricity and pump water for the town.

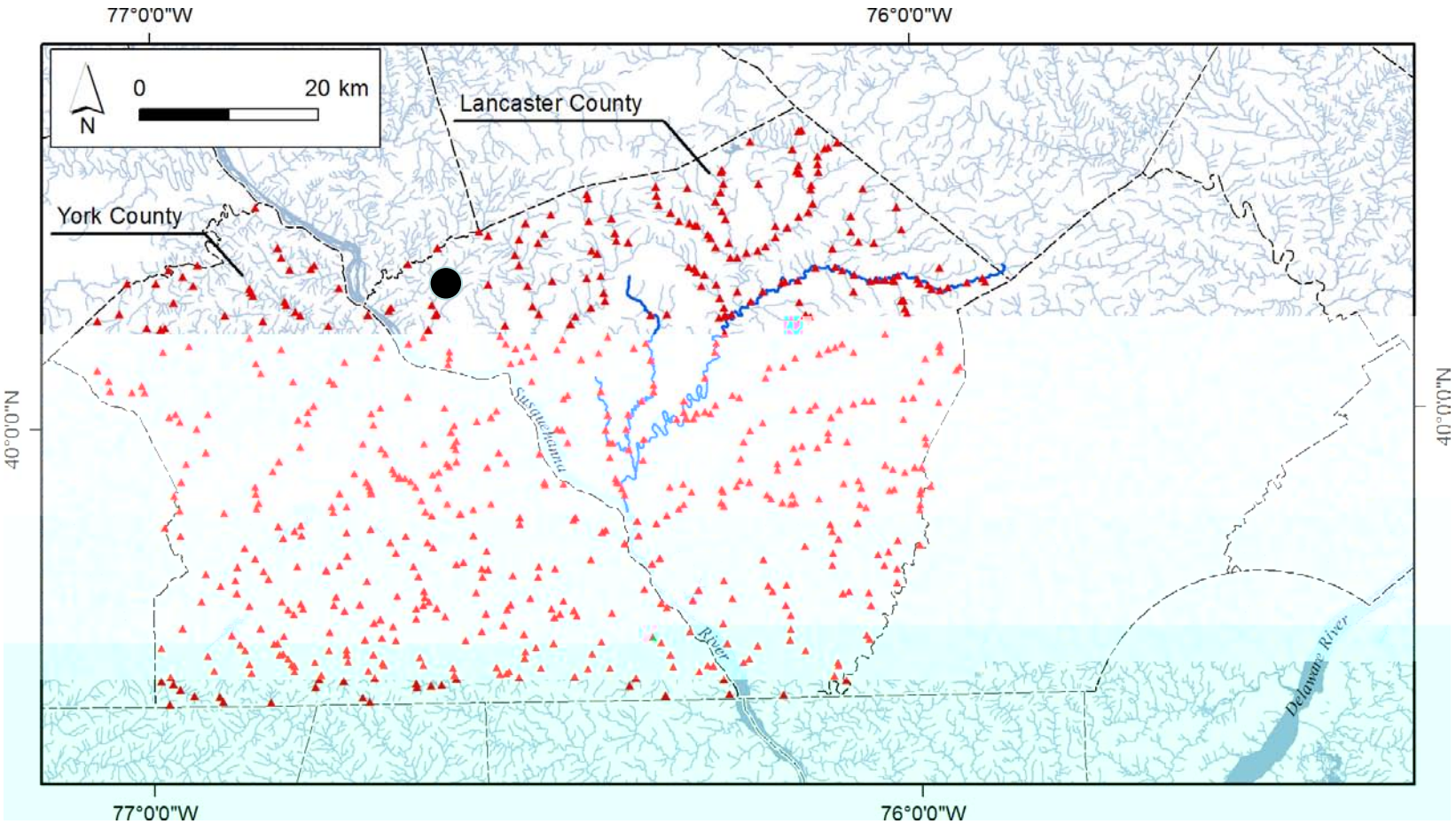
"There is no neighborhood in any part of the United States without a water gristmill."
Thomas Jefferson, 1786



~400 mill dams in 19th C. Atlases of Lancaster County

▲ **Location of mill dams**

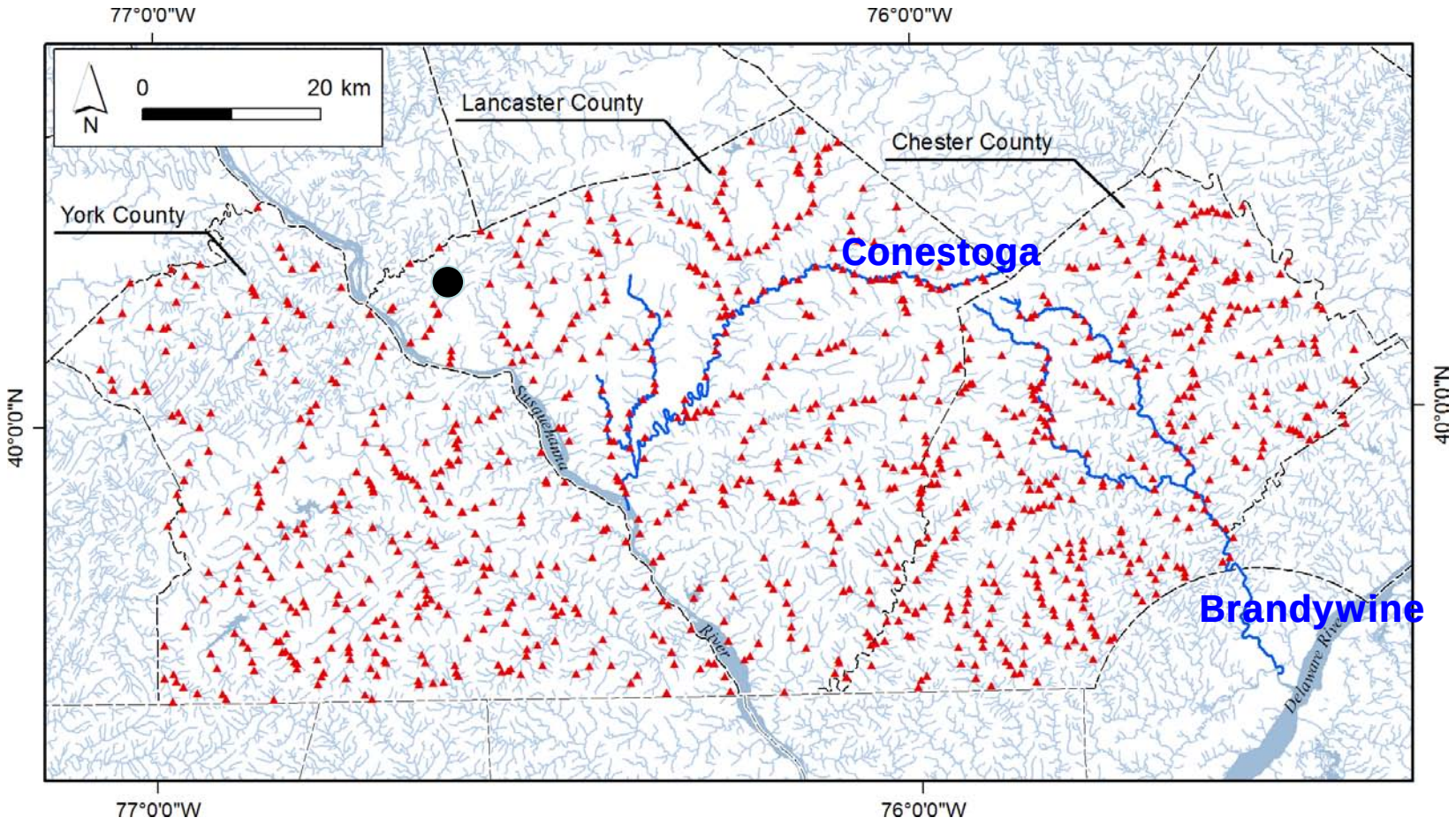
"There is no neighborhood in any part of the United States without a water gristmill."
Thomas Jefferson, 1786



~800 mill dams in 19th C. Atlases of York and Lancaster Counties

▲ **Location of mill dams**

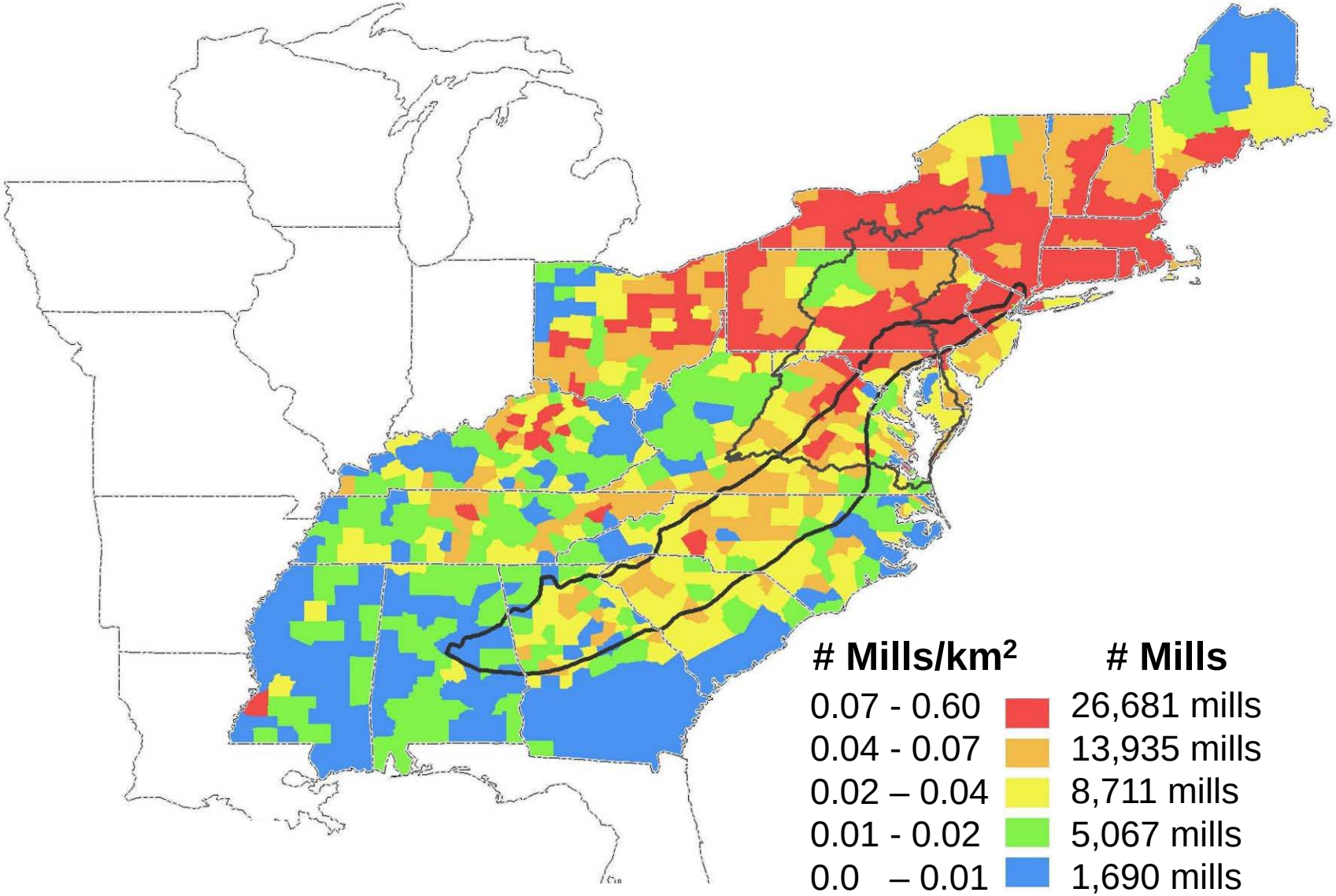
http://edisk.fandm.edu/michael.rahnis/ex-census.html



Over 1,000 mill dams in 19th C. Atlases of York, Lancaster & Chester Counties

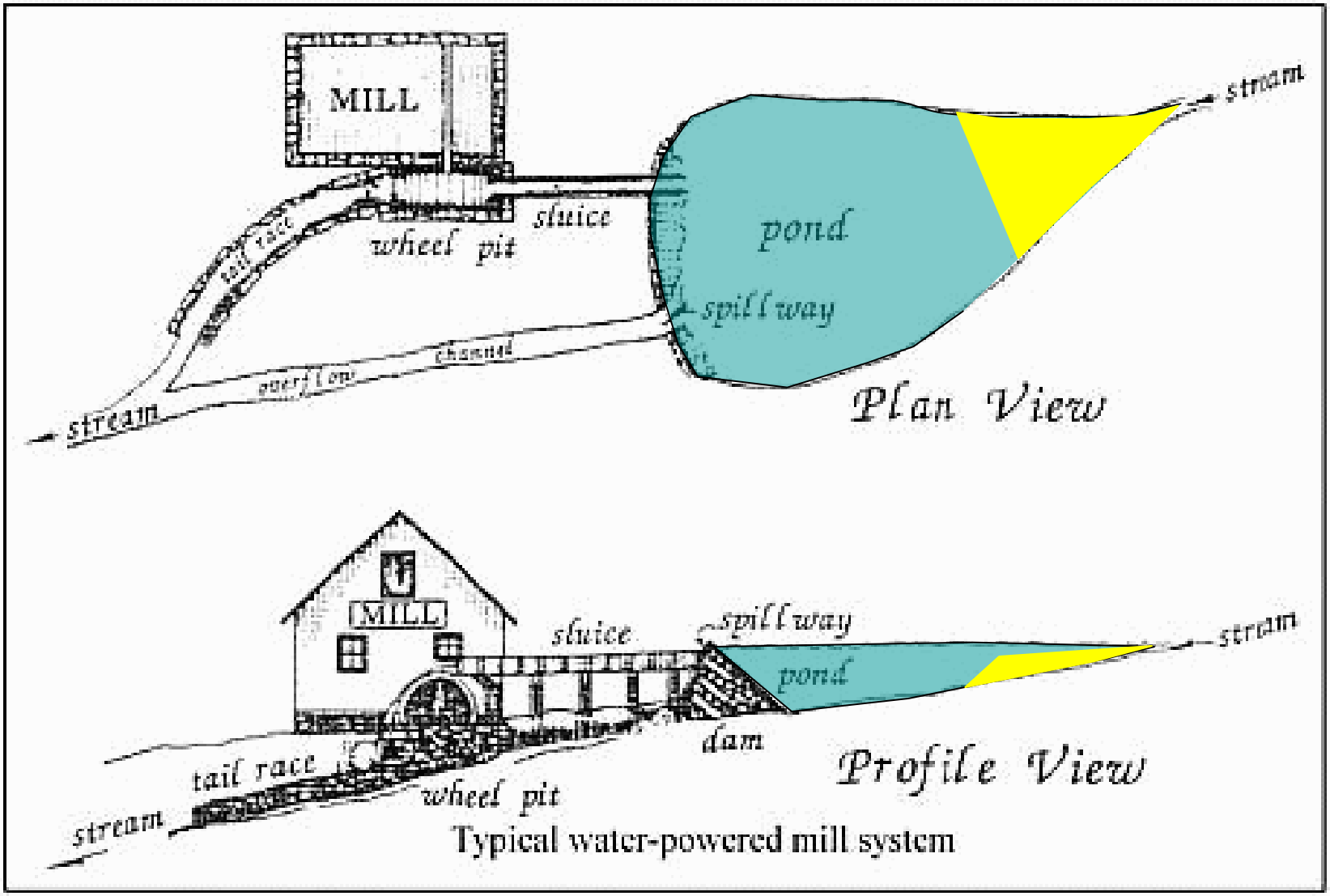
▲ **Location of mill dams**

"There is no neighborhood in any part of the United States without a water gristmill."
Thomas Jefferson, 1786



Mill Density from 1840 US Census
~65,000 Water-powered Mills

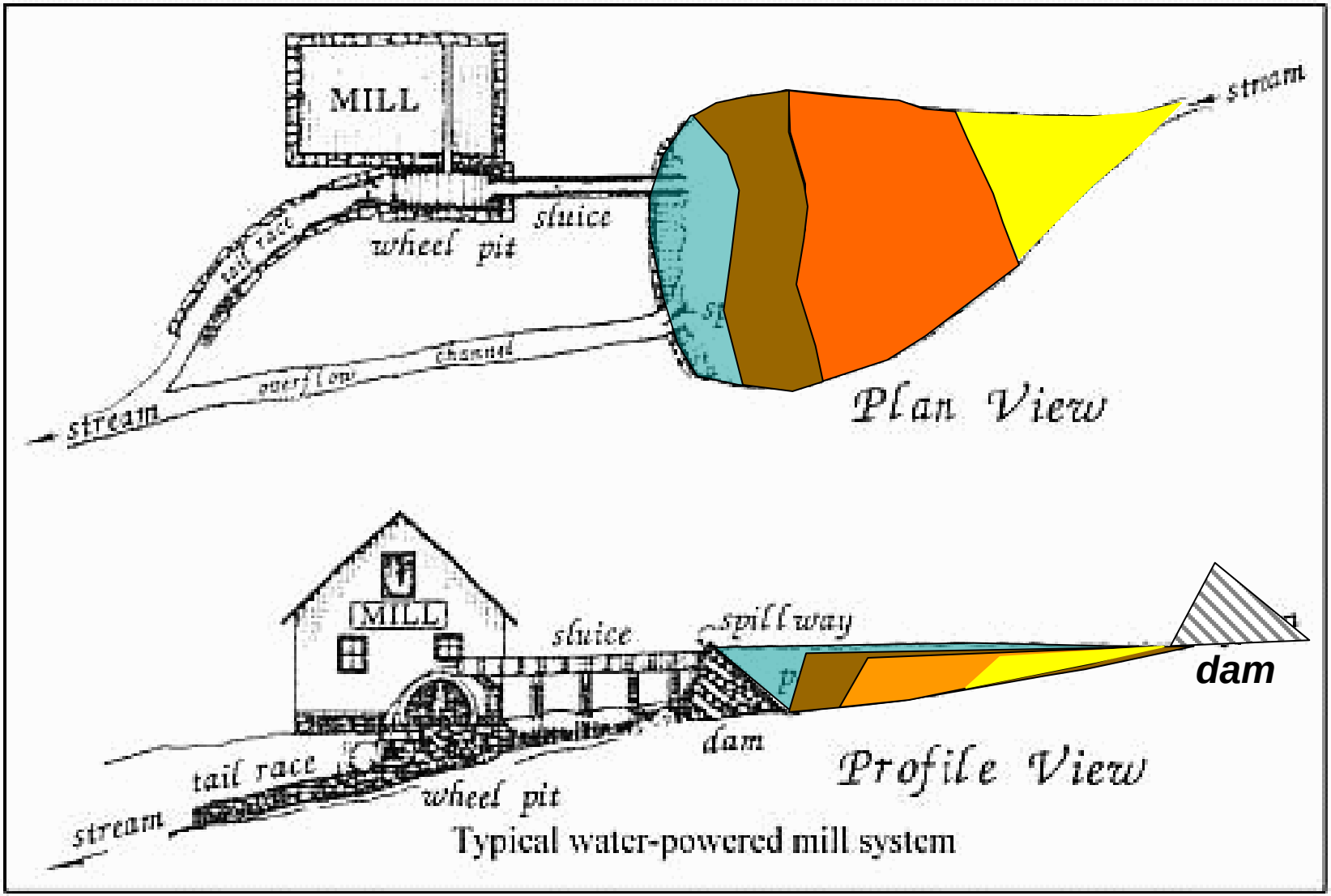
Impact of Water-Powered Mill Dams on Sediment Storage in Valleys



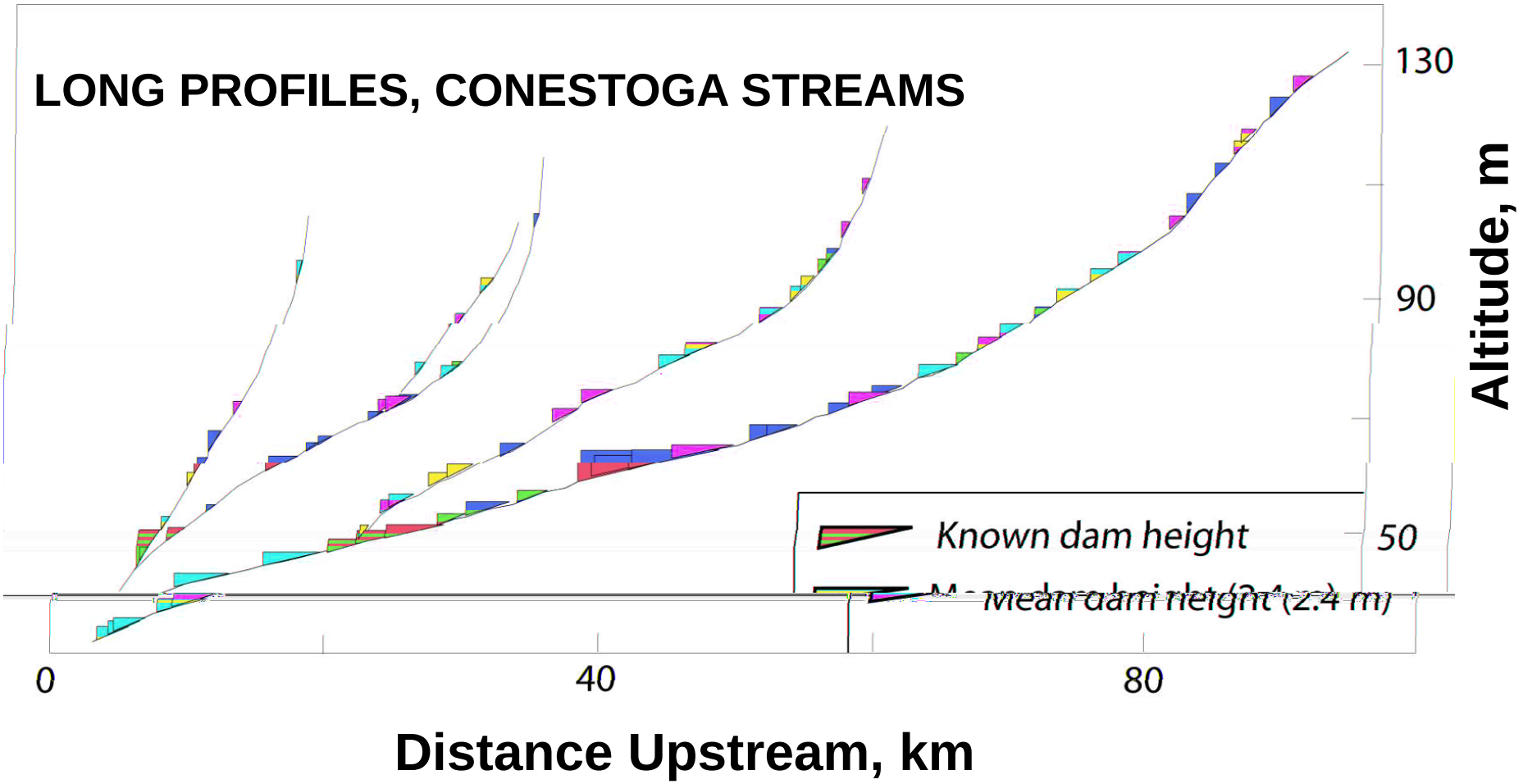
Typical water-powered mill system

From: Mills on the Tsatsawassa: Techniques for Documenting Early 19th Century Water-Power Industry in Rural New York, by Philip L. Lord

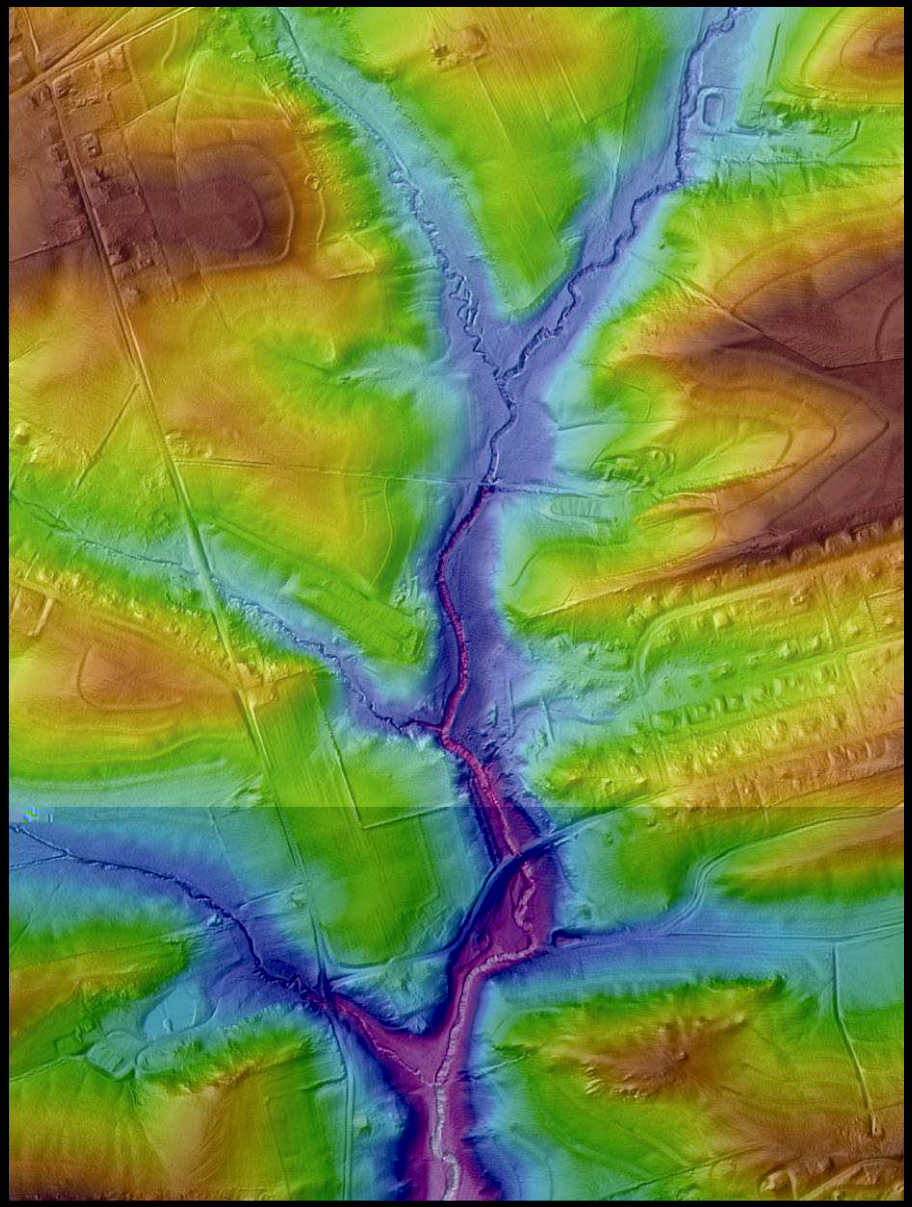
Impact of Water-Powered Mill Dams on Sediment Storage in Valleys



Typical water-powered mill system


LONG PROFILES, CONESTOGA STREAMS
130
90
50
Altitude, m
Known dam height
Mean dam height (2.4 m)
0
40
80
Distance Upstream, km

Science Cover, January 18, 2008

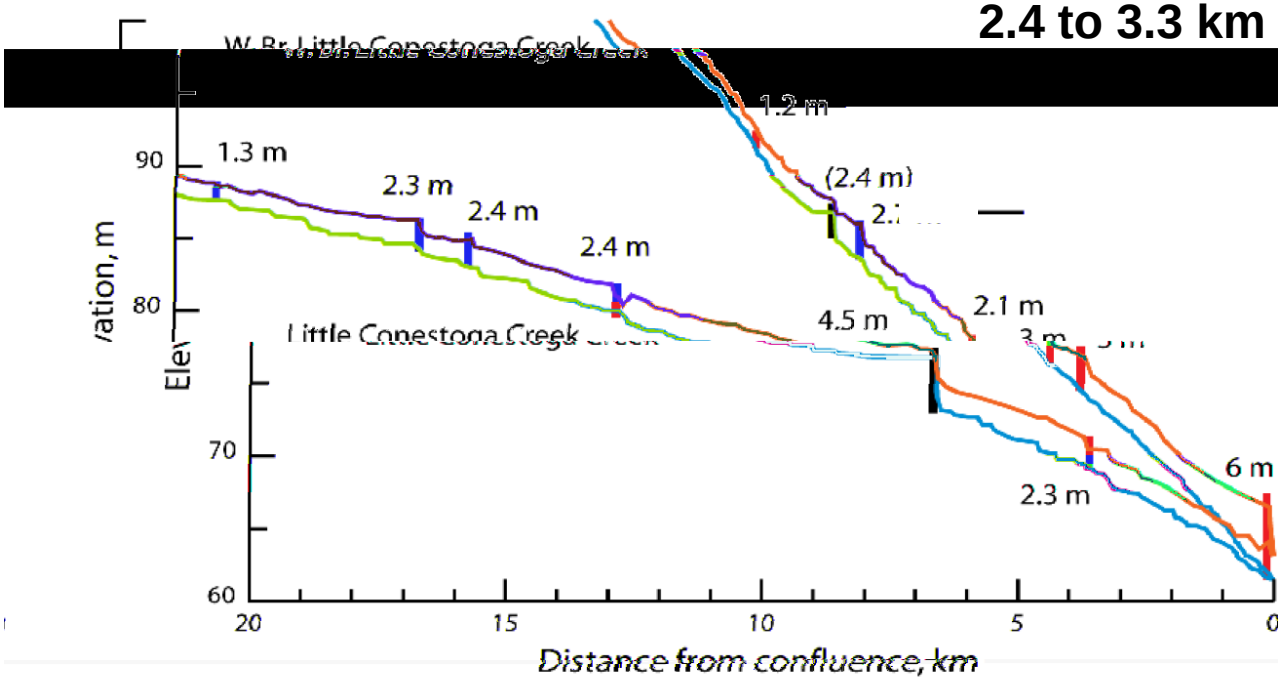


Walter and Merritts, 2008

LIDAR, ~15 cm vertical resolution, 25 cm horizontal

Sediment storage in valleys

Average dam height 2.4 to 3 m;
Average mill pond length
2.4 to 3.3 km



Lidar analysis (15 cm vertical resolution)

Sediment storage in valleys

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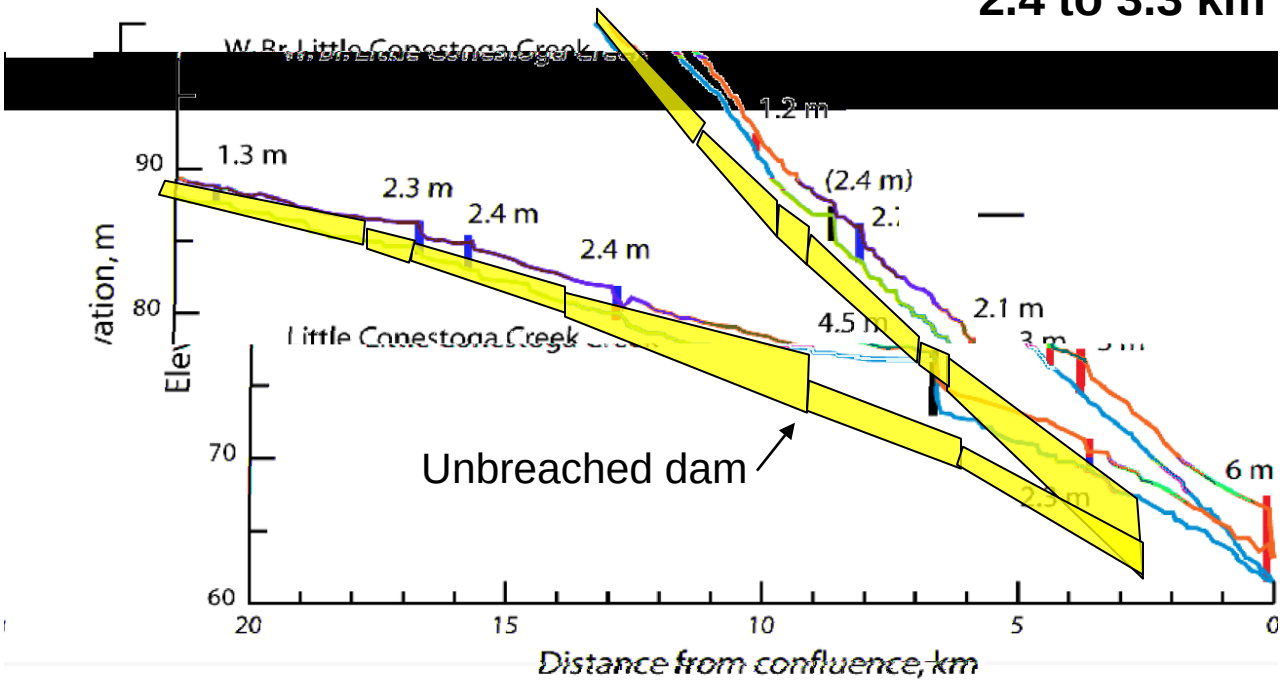
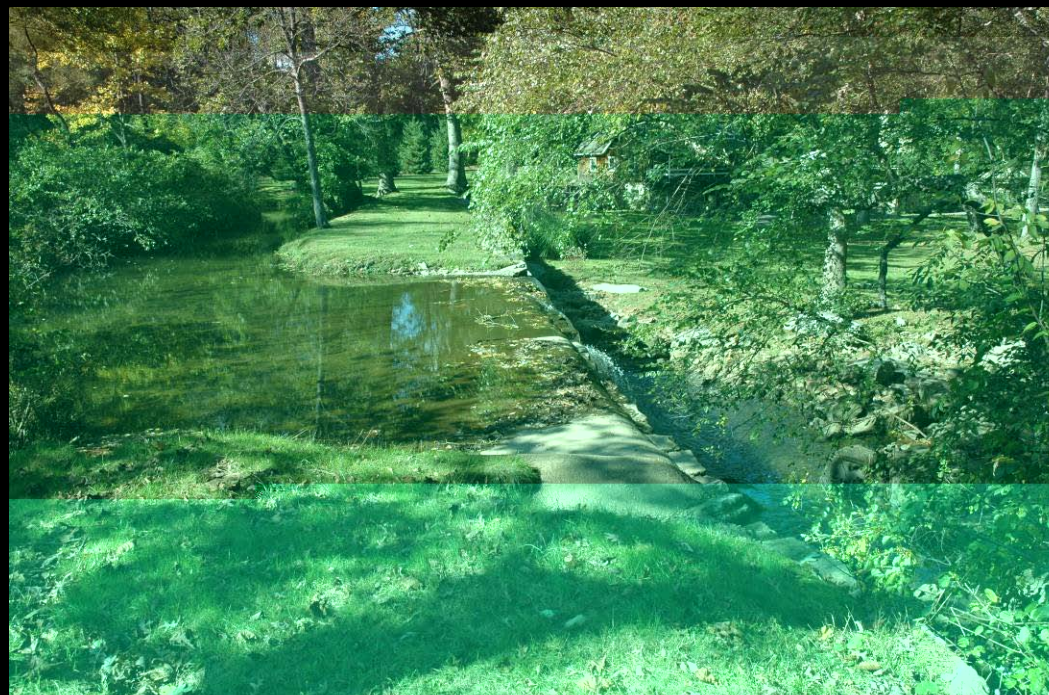


Lidar analysis (15 cm vertical resolution)

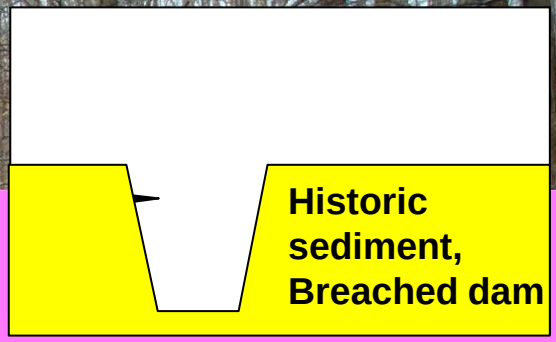
Unbreached dam:

Pickering Creek Mill Dam (~3 m), Chester County, PA

Historic sediment, unbreached dam



Breached Earthen Dam: Panther Branch, MD



Crest of 19th c. earthen dam

Fine-grained mill pond sediment wedge

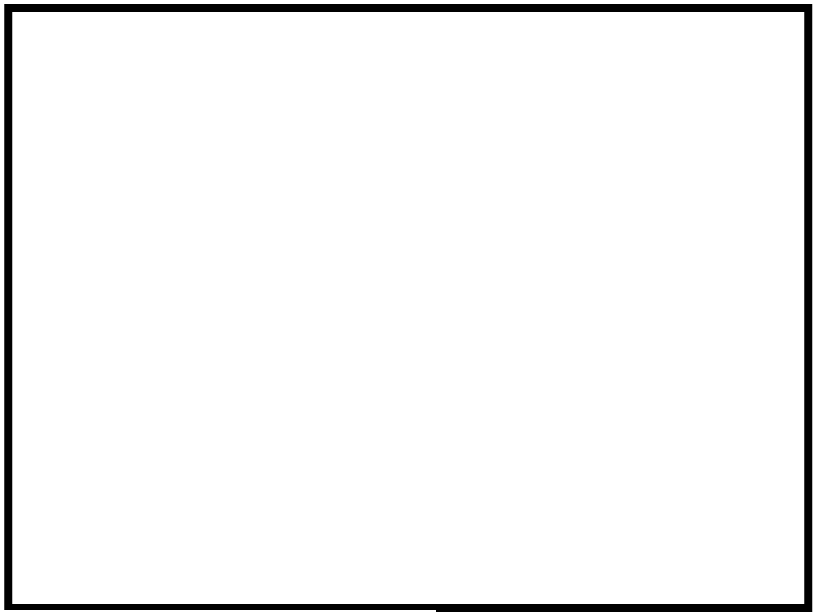
flow

What happens once a mill dam breaches?

Flume experiments provide experimental analogs.

Flume experiments and video footage from
Dr. Allesandro Cantelli, University of Minnesota
http://www.nced.umn.edu/Stream_Restoration_Toolbox.html

Flume Studies: Base level matters for dam removal and breaching



Resembles a Typical Piedmont Stream

Flume Studies: Base level matters for dam removal and breaching

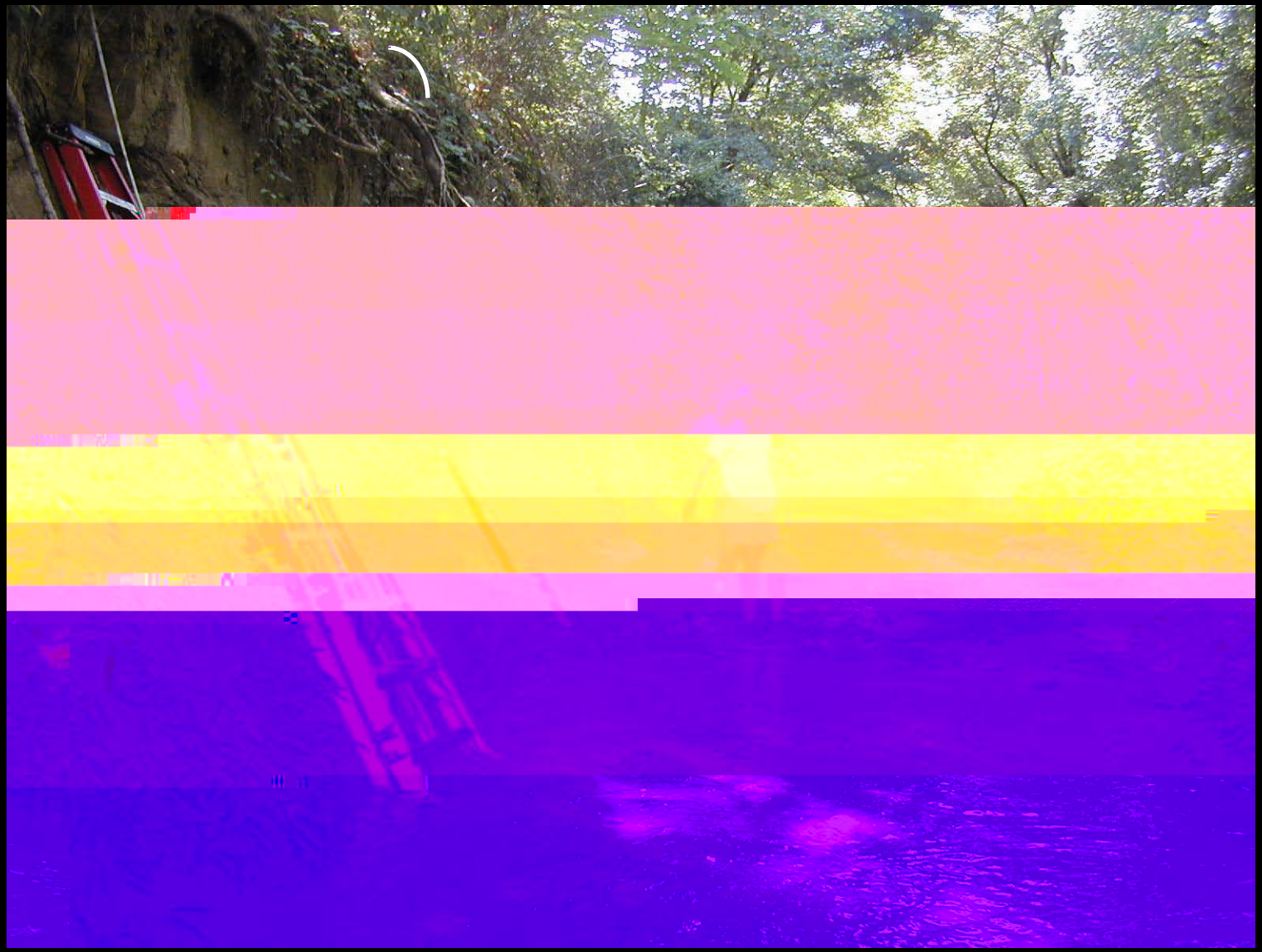
Resembles a Typical Piedmont Stream

Base level drops with dam removal and breaching

Big Spring Run: Typical Piedmont Stream

What was the landscape before milldams, ponds, and muds?

Mill Pond Reservoir Sediment Stack

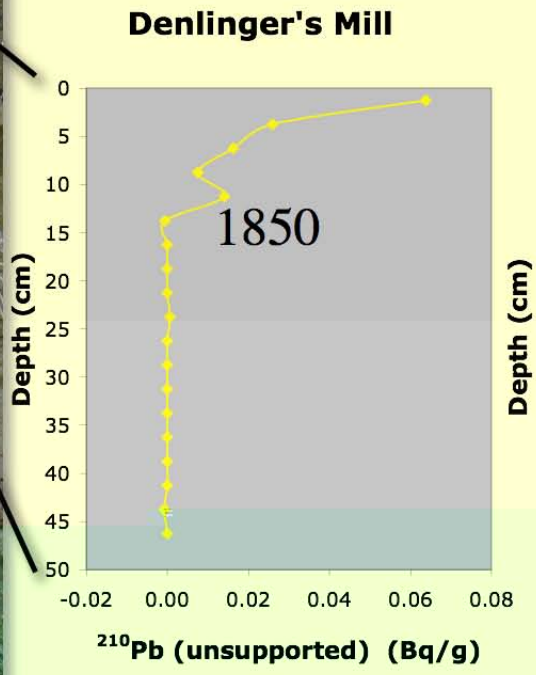


Denlinger's Mill, W. Br. Little Conestoga, PA

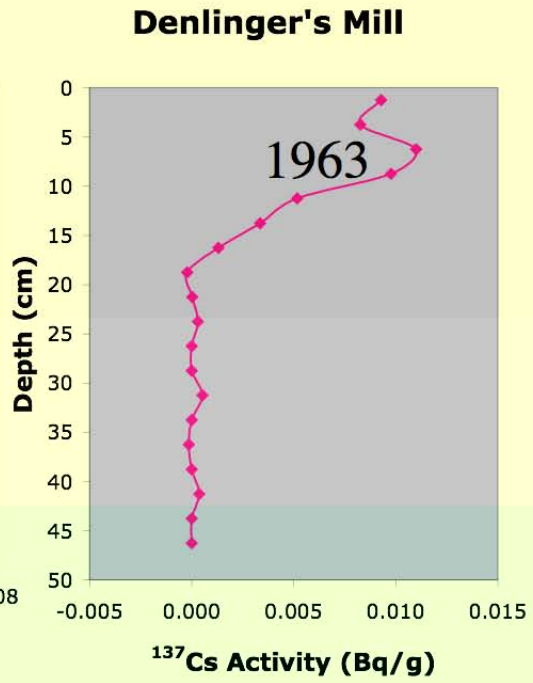
Denlinger's Mill Stream Bank

Geochronology

^{210}Pb



^{137}Cs

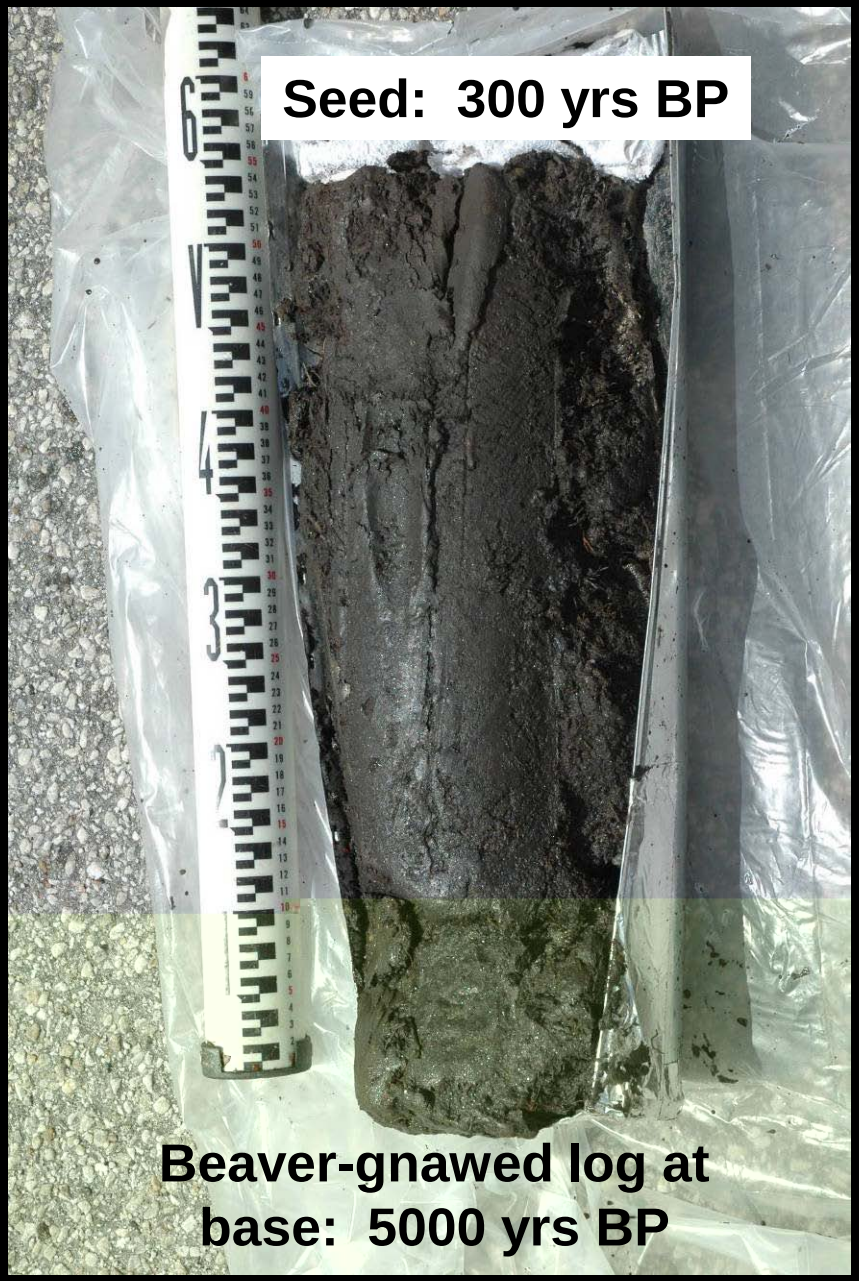


✧ AMS Dates

Reconstructing Past Landscapes and Ecosystems from Buried Soils

Going deeper and farther back in time…..to buried Holocene soils and Pleistocene deposits…….early Colonial and native American artifacts

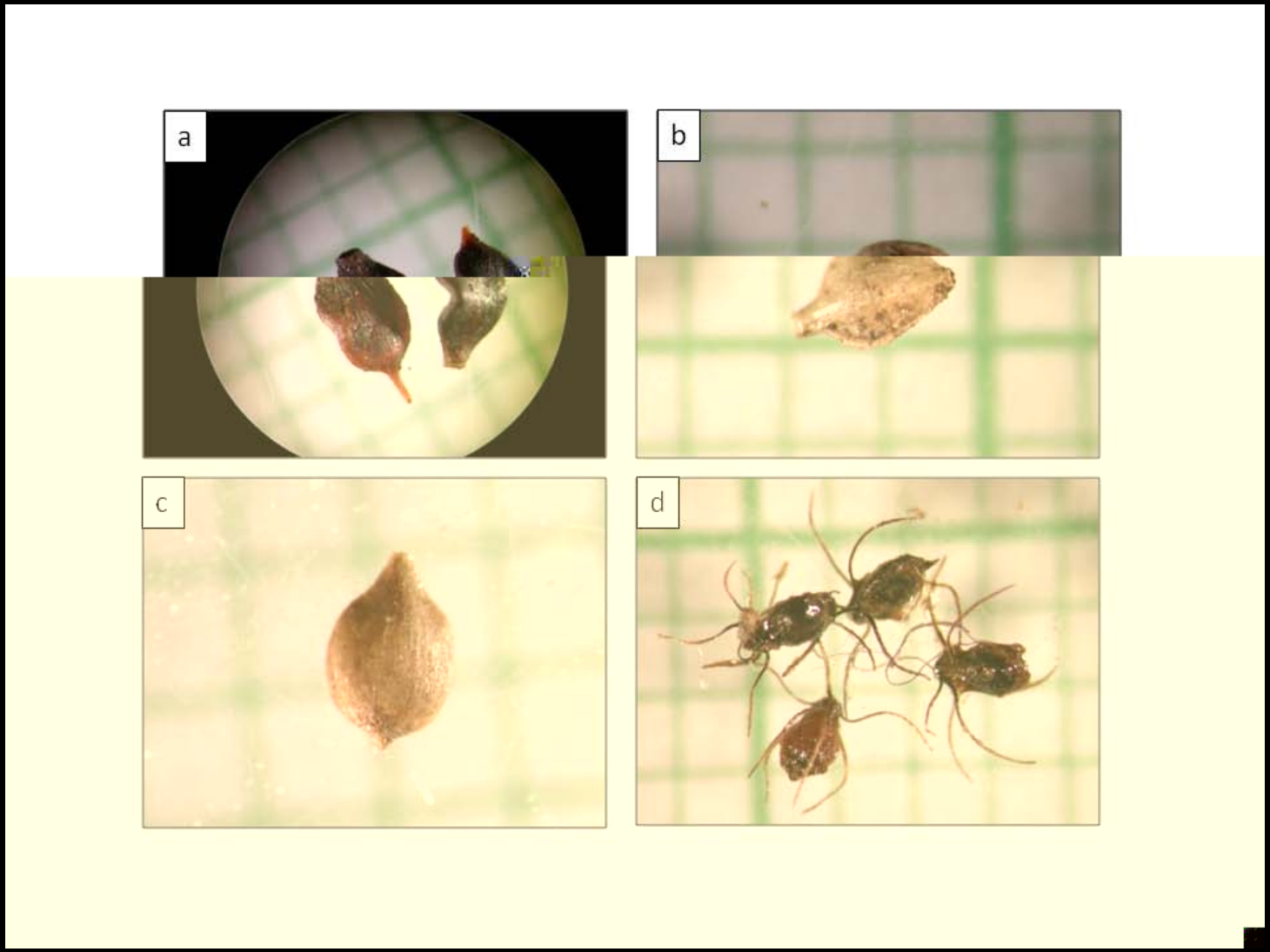
Holocene peat core, wetland seeds



Alder sp. (OBL) [Alder]

mm scale

Carex sp (OBL) [sedge]


a
b
c
d

)

)

)

)

Modern Analog for Pre-settlement Valley Bottom Wetlands

Jones Falls, MD

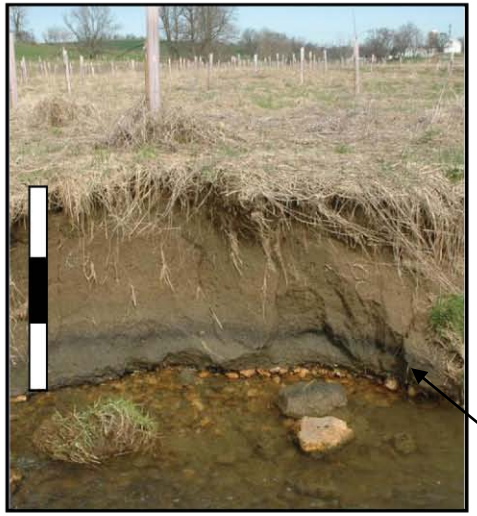
Time Matters: **Climate and Vegetation Change in the Holocene are Documented in Pre-Settlement Fluvial-Wetlands**

A

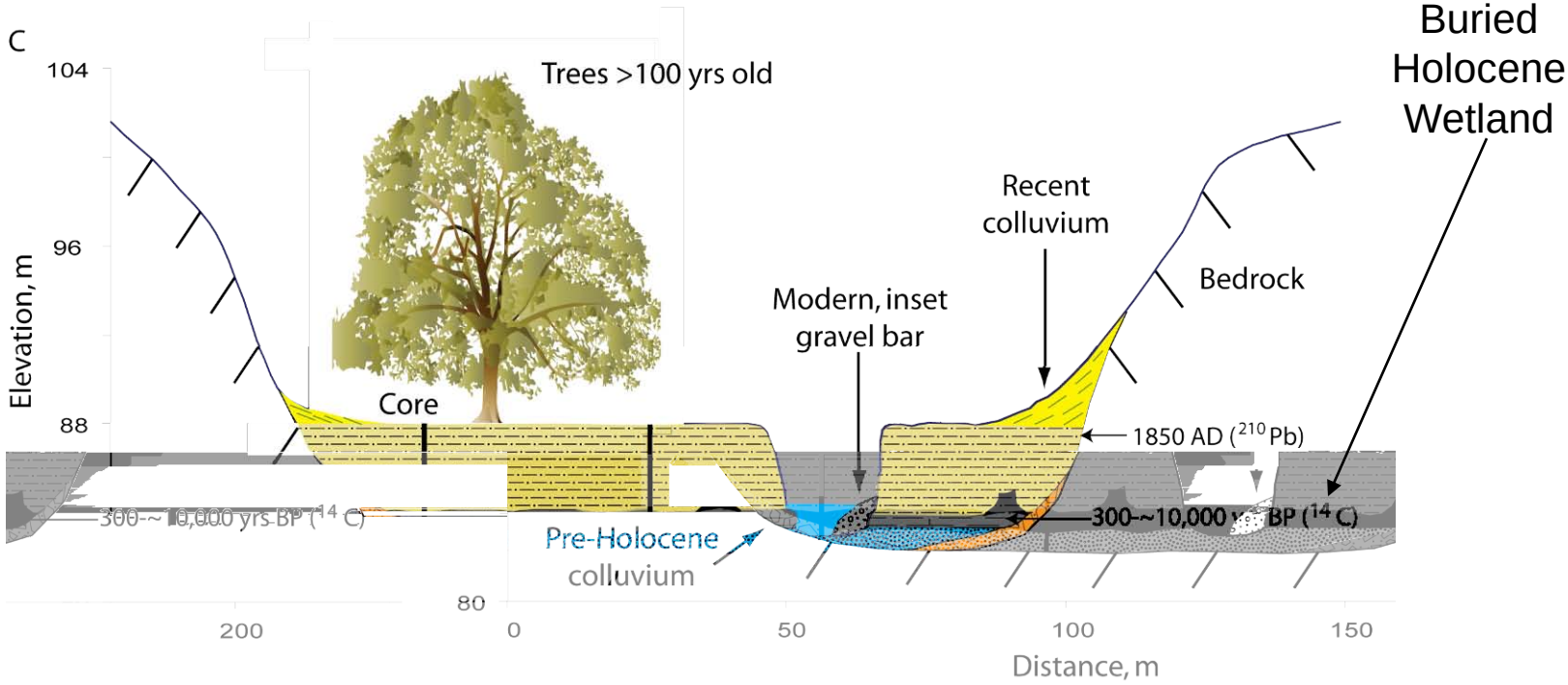
Western Run, MD

B

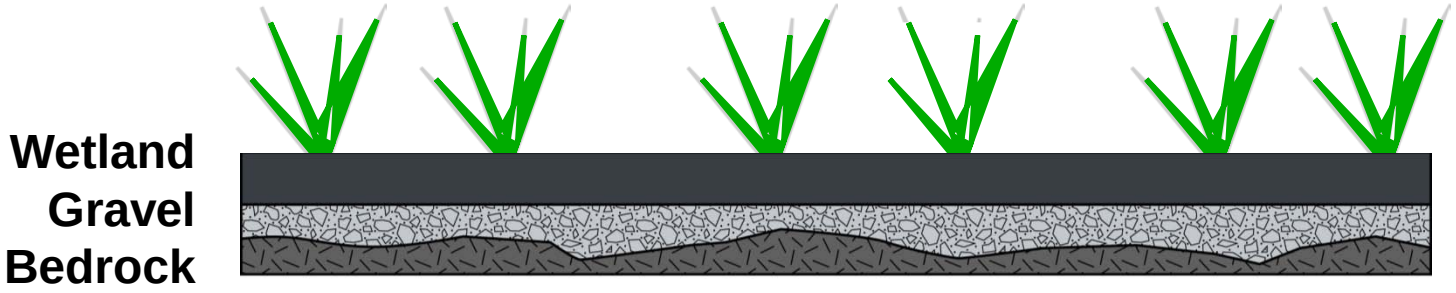
Big Spring Run, PA



C

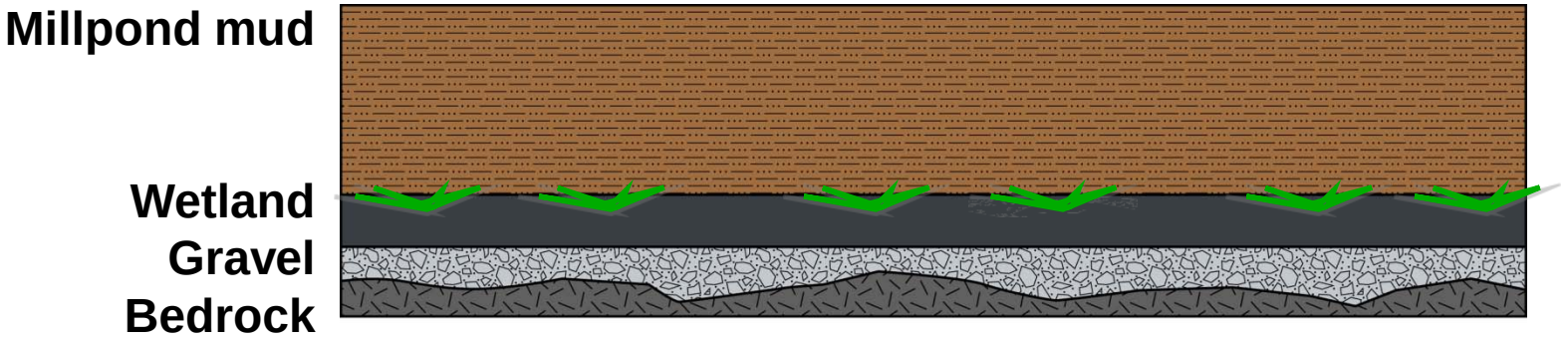


Holocene (pre-settlement) wetlands on Pleistocene gravel

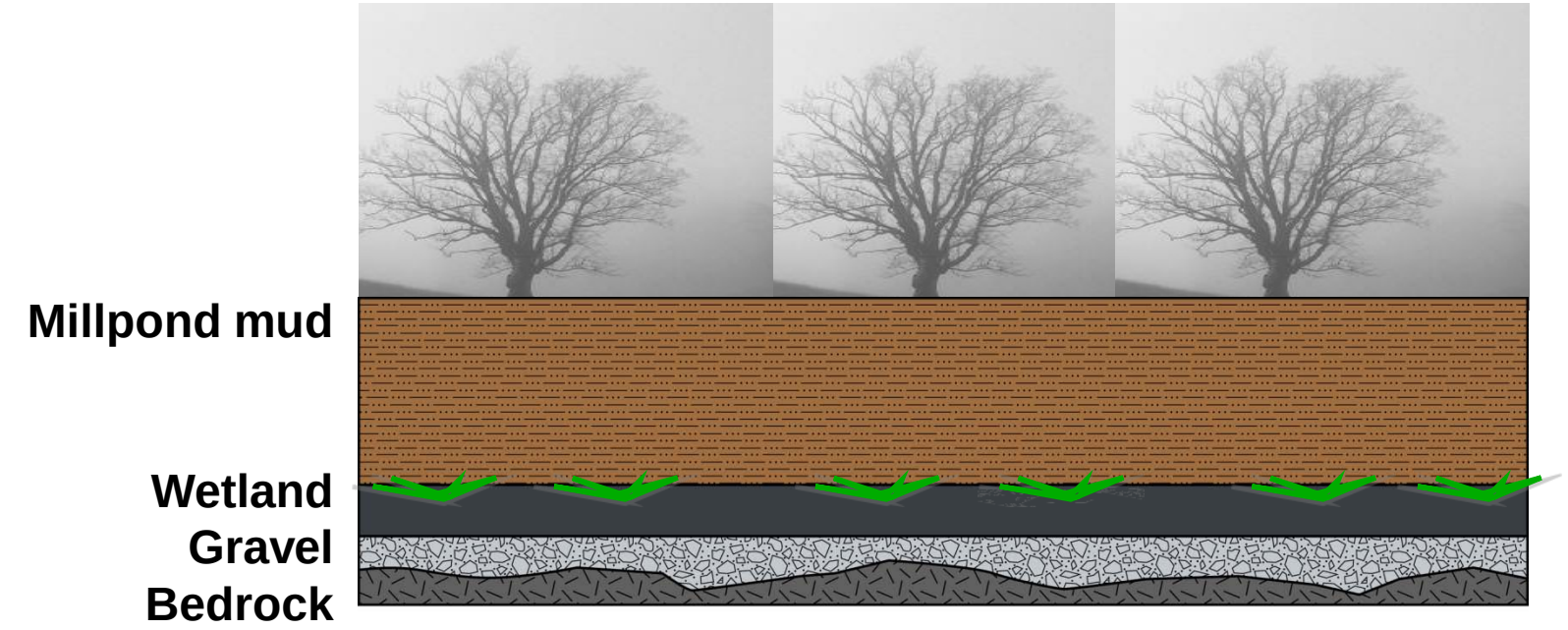


Wetlands from valley wall to valley wall,
and no evidence of buried single-thread stream channels

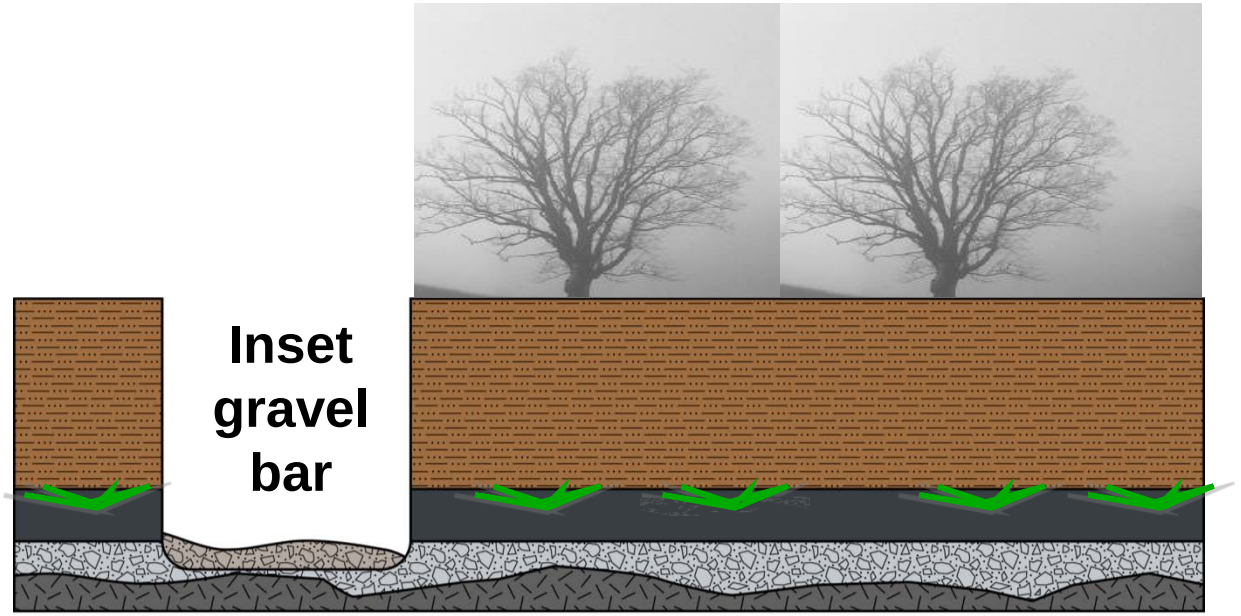
Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel

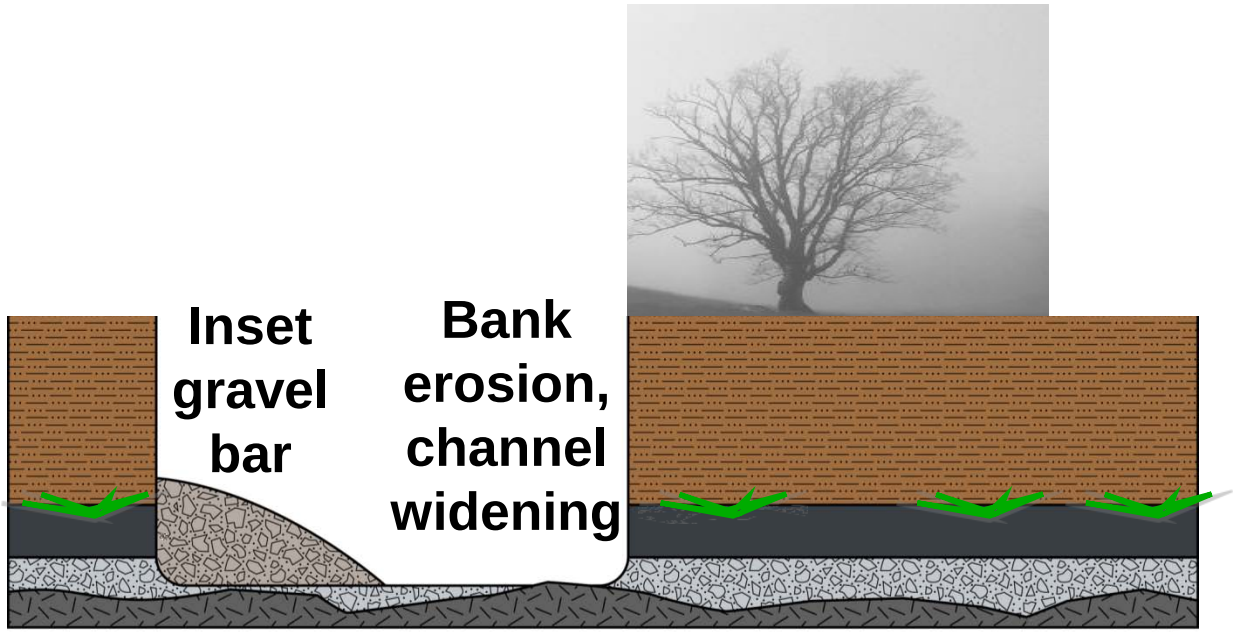


Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



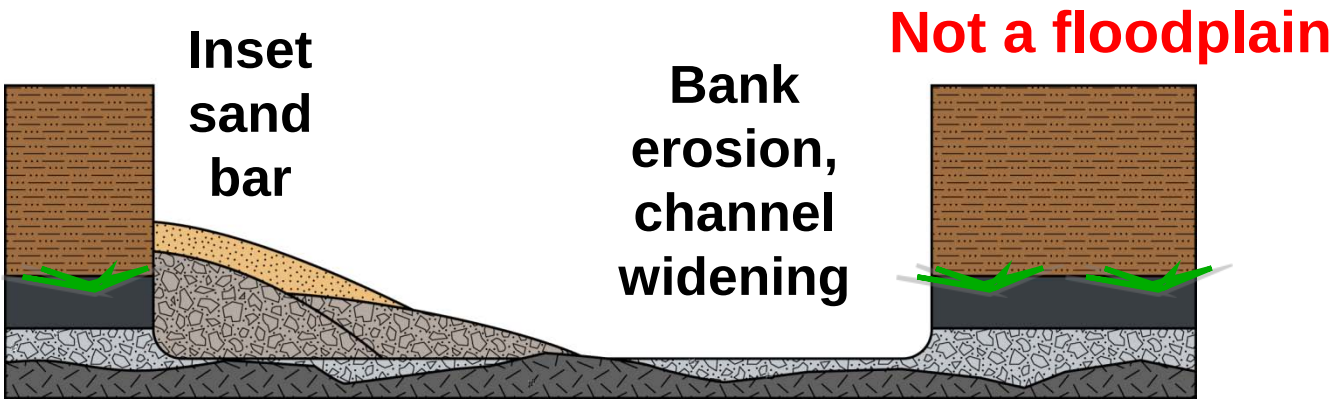
Modern inset sand/gravel bars

DAM BREACH



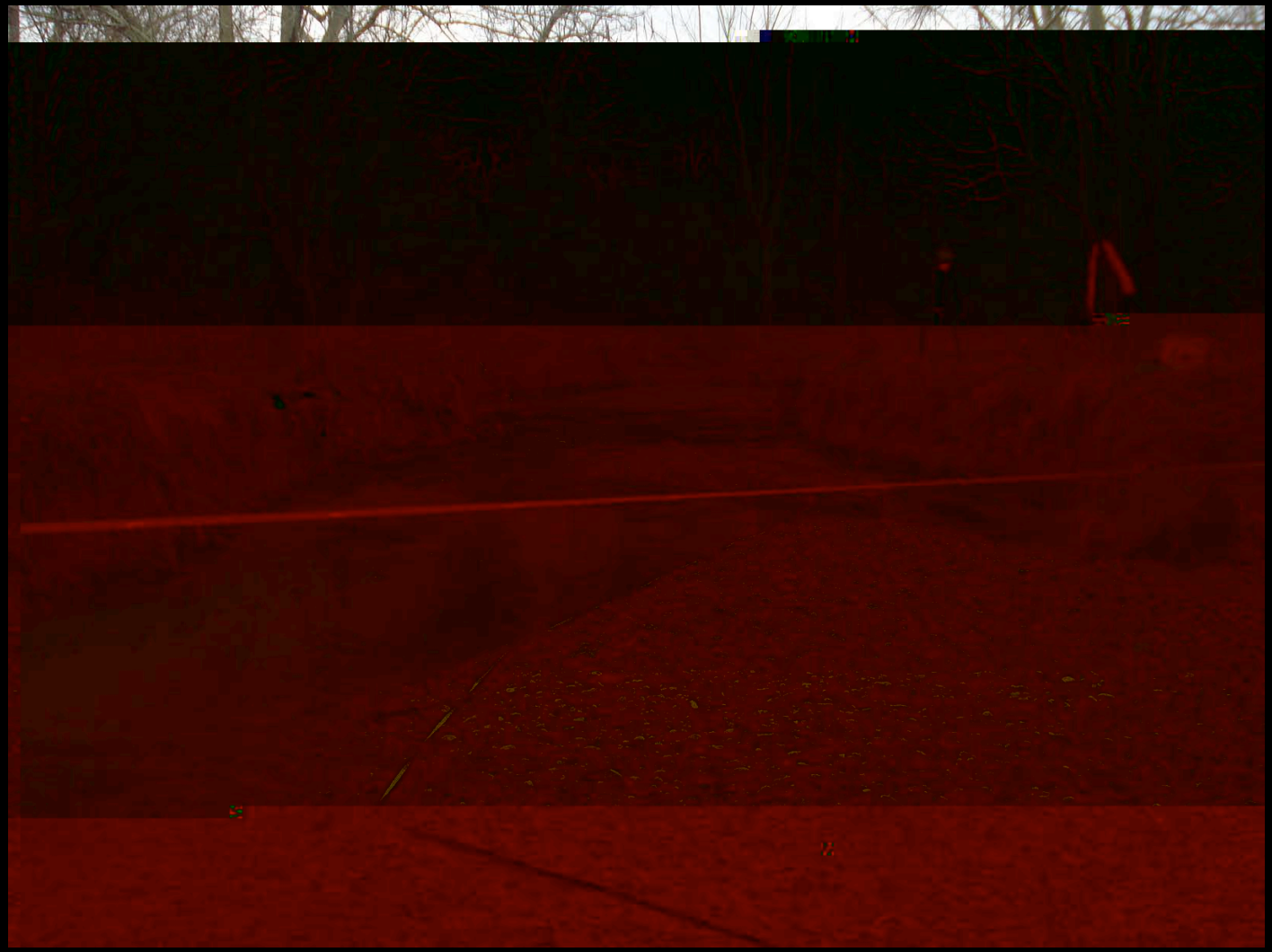
With time, width increases and depth decreases for a given runoff event, thus shear stress decreases.

Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



With time, width increases and depth decreases for a given runoff event, thus shear stress decreases.

Anthropocene Streams



Pleistocene gravel, Holocene wetlands and grasslands (?), and historic millpond mud

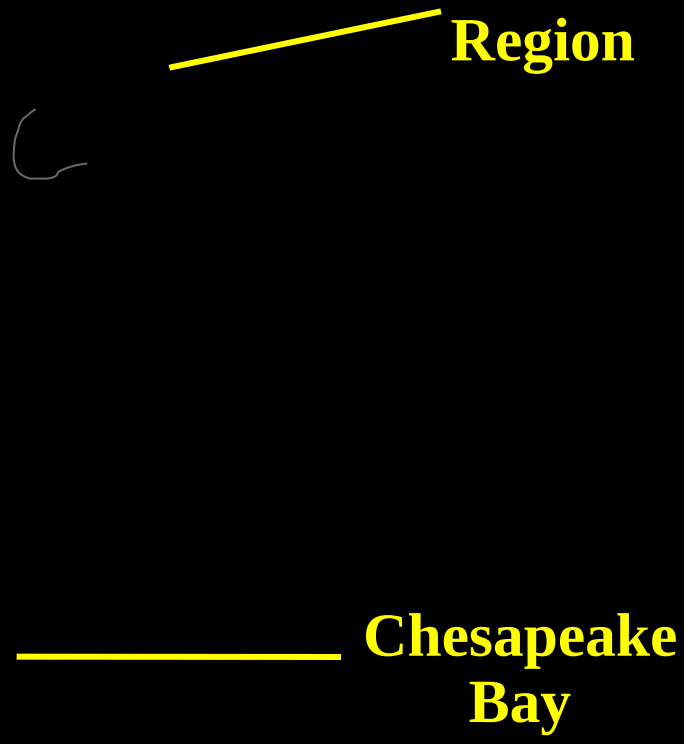
Conoy Creek, Elizabethtown
Masonic Villages Stream Restoration

Susquehanna broadspear beneath mill pond sediment

~4000 yrs old

THE “GREAT SEDIMENT EXPERIMENT”

- Piedmont lowlands
- Relief 120 m
- 50% slopes <7%
- Thick silt loam soils
- Carbonate/schist



Conoy Creek Before Restoration

03-12-2008

05-15-2008

After Restoration

5-10-2010

5-10-2010

THE END

What can be done about erosion and sediment in the Chesapeake Bay?

Seneca Creek, MD
(Eastern USA Piedmont)

New Fork River, Pinedale Wyoming,
with gravel bar

Seneca Creek, MD (Eastern USA Piedmont)

River Flood Plains: Some Observations On Their Formation

By M. GORDON WOLMAN and LUNA B. LEOPOLD

PHYSIOGRAPHIC AND HYDRAULIC STUDIES OF RIVERS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 282-C

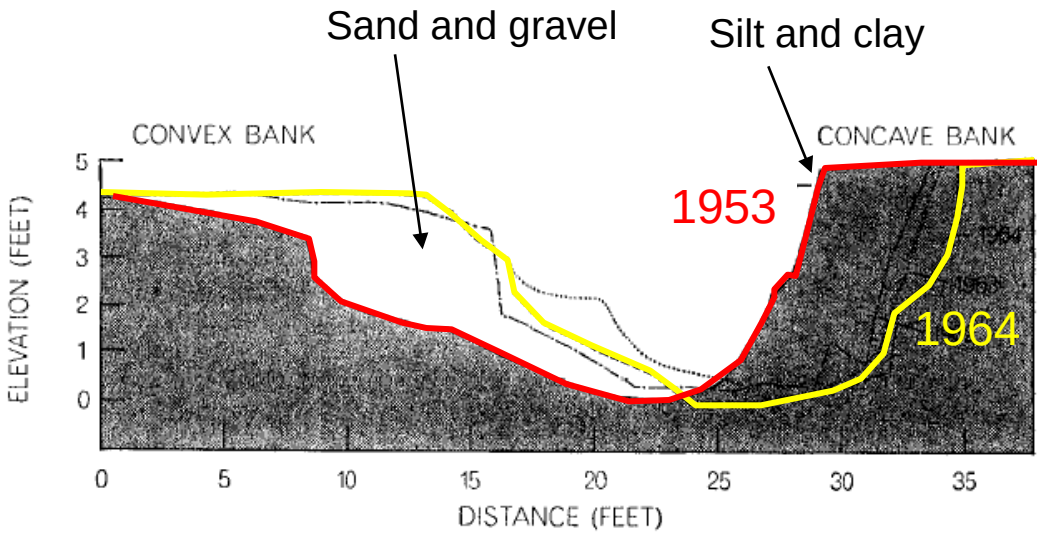
Walter and Merritts, 2008:

- Banks along eastern streams are fine-grained (silt, clay, and fine sand), whereas beds are generally gravel, and the two have different origins and ages.
- Eastern and western streams did not form by the same processes.
- Most eastern stream banks are not self-formed floodplains. They are reservoir fill terraces.

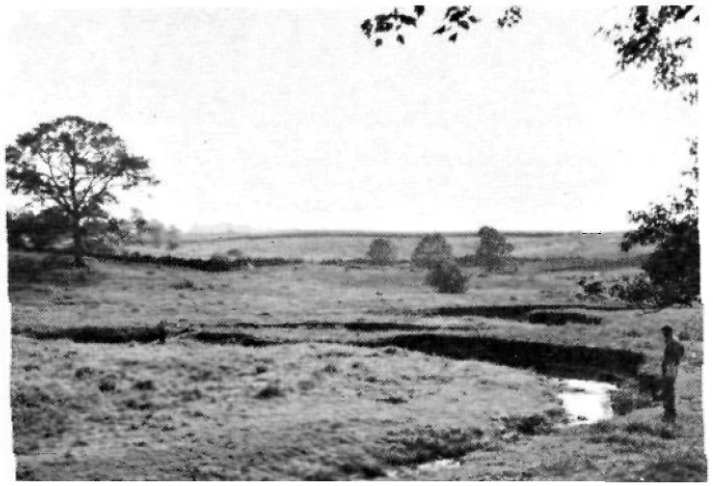
New Fork River, Pinedale Wyoming, with gravel bar

THE MODEL FOR WATTS BRANCH, MD—WOOTTONS MILL PARK

Conclusions from *Wolman and Leopold, 1957:*
Meandering streams and bank erosion are <u>natural, long-term processes</u>.
Streams erode one bank and deposit bars on the other.



Lateral migration at "typical meander" from 1953 to 1964, Watts Branch, small tributary to Potomac River. *"The lateral migration of meanders by erosion of concave banks and deposition on convex banks <u>over many years</u> results in a river channel's occupying every possible position between valley walls."*



Floodplain of Watts Branch with point bar (Wolman and Leopold, 1957). Basis for classic conception of meandering streams was breached 19th *c.* mill pond.

WATTS BRANCH, MD—WOOTTONS MILL PARK

Restoration Rationale: Urbanization leads to incision, accelerated meander migration, and channel widening. Unfortunately, the problem was mis-diagnosed. The actual problem was a partially breached mill dam, and a 2-m stack of mill pond silt and clay.

2005

2008

"During his 20-year tenure with the U.S. Geological Survey, Luna Leopold made a personal project of monitoring Watts Branch, a meandering stream near Rockville, Maryland…. **It flowed through a cow pasture then; now it is surrounded by suburban housing.**" (Brian Hayes)

Watts Branch stream restoration 2 years later in 2007

Natural Stream Chanel Design: "Morphologically defined as the *ability of the stream to maintain, over time, its dimension, pattern, and profile* in such a manner that it is neither aggrading nor degrading and is able to transport *without adverse consequences* the flows and detritus of its watershed". (From Rosgen, Applied River Morphology, 1996)

BEFORE, 2004

Banta Floodplain/Wetland Restoration, Lititz Creek

LandStudies, Inc.

AFTER, 2007

BIG SPRING RUN, LANCASTER COUNTY, PA,WETLAND-FLOODPLAIN RESTORATION EXPERIMENT

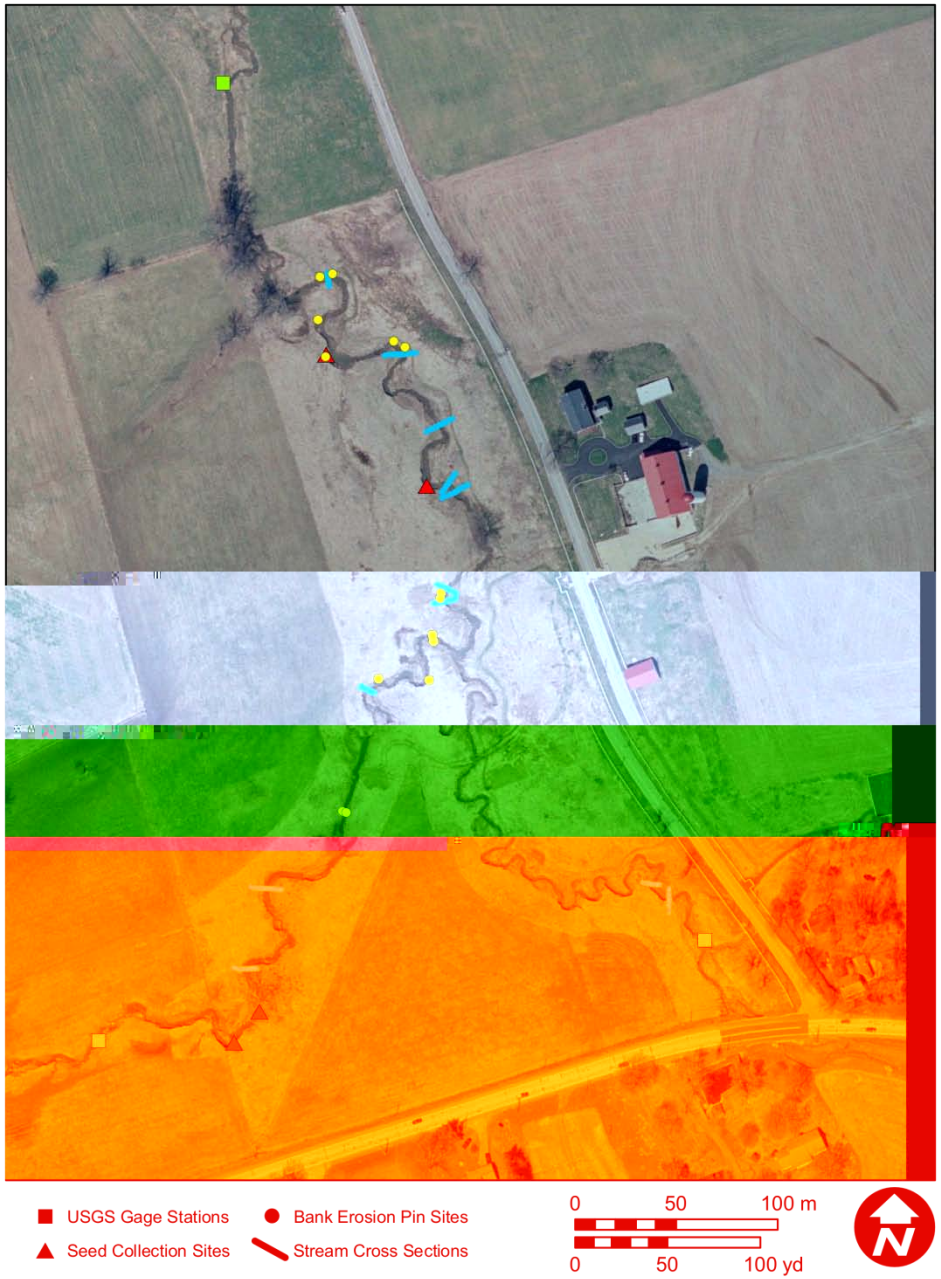
Partners: USGS, PA DEP, US EPA, F&M COLLEGE, LANDSTUDIES, PEC

USGS Gage Stations

Seed Collection Sites

Bank Erosion Pin Sites

Stream Cross Sections



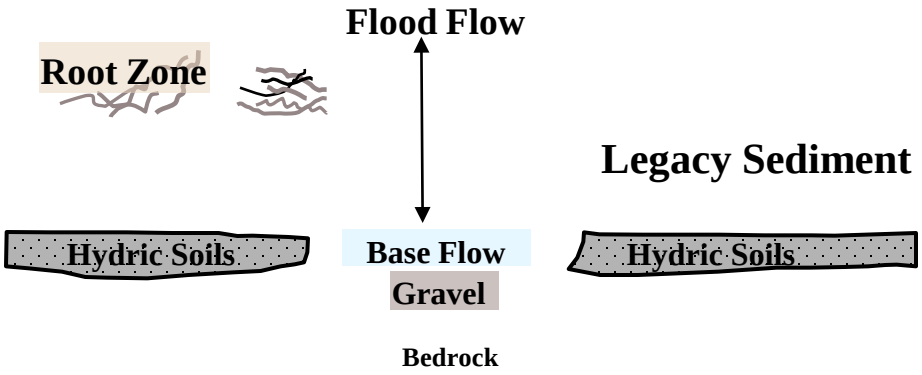
IN CLOSING

The value of building teams of collaborators that include students of different ages and levels of background and experience, and of merging scientific understanding with policy and engineering.

The importance of thinking outside the box and acknowledging the ways in which scientists develop and revise ideas.

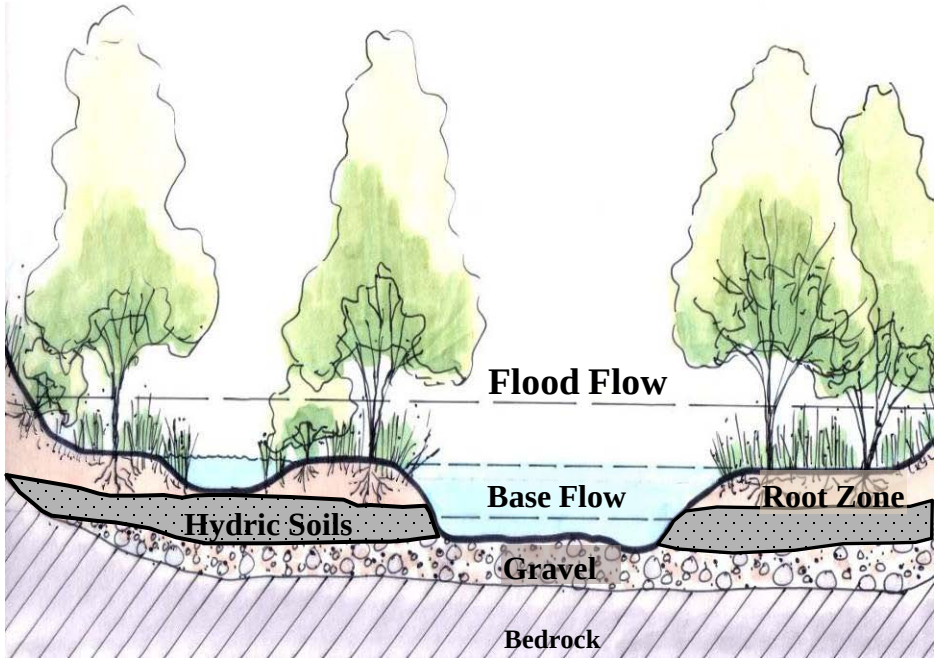
The modern environmental challenge of figuring out how to restore streams and wetlands in landscapes that have been disturbed in multiple ways for centuries. Diagnosing the problem is difficult and we are saddled with misconceptions.

Existing Condition



- The existing condition formed rapidly as a result of widespread upland soil erosion and fine-grained sediment storage in valley bottoms of the Mid-Atlantic Region
- After dam breaching, streambank erosion of legacy sediment represents a significant sediment and nutrient source in some watersheds
- High quality, naturally formed, and indigenous aquatic resources are buried under legacy sediment and impaired in our modern environment

Natural Condition



- The natural condition formed under long-term geologic and climatic processes and represents truly indigenous aquatic resources in the Mid-Atlantic Region
- The indigenous aquatic resources are natural and stable ecosystems that function as nutrient and sediment sinks, sources of groundwater recharge and discharge (cool water springs and base-flow to streams), and zones of highly concentrated biota
- The natural condition represents the best future condition and restoration goal

Floodplain and Riparian Wetland Restoration BMP

- The proposed BMP is an ecological restoration and management strategy.
- Restoration and management actions are proposed to re-establish natural stream, wetland, floodplain and riparian condition and function.
- Implementing the practice will target legacy sediment.
- Monitoring at future implementation sites (e.g., Big Spring Run) is necessary to quantify and document the BMP benefit.
- Understanding and recognizing the role that legacy sediment plays in modern environmental conditions and impairments will improve aquatic resource restoration strategies in the Mid-Atlantic Region.

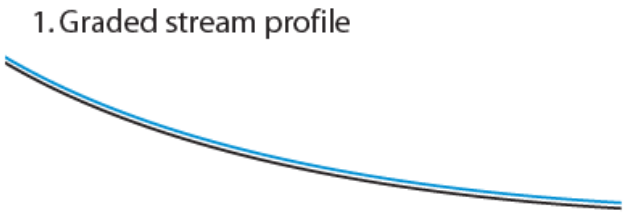
Links to Our DEP Report and GSA Field Guide:

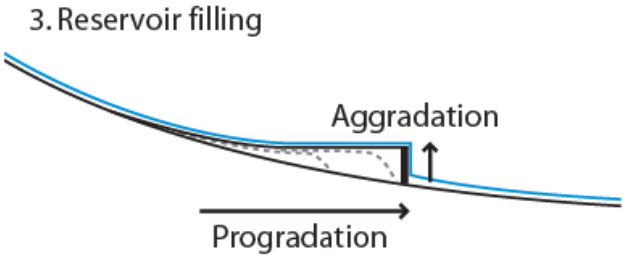
http://edisk.fandm.edu/dorothy.merritts/report.html

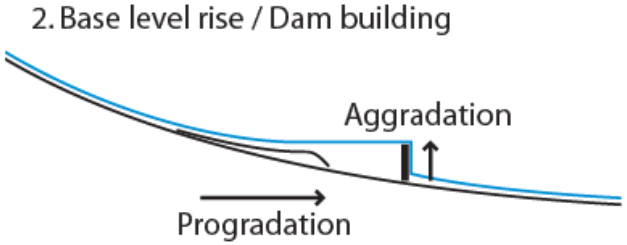
http://edisk.fandm.edu/robert.walter/gsa-fieldguide.pdf

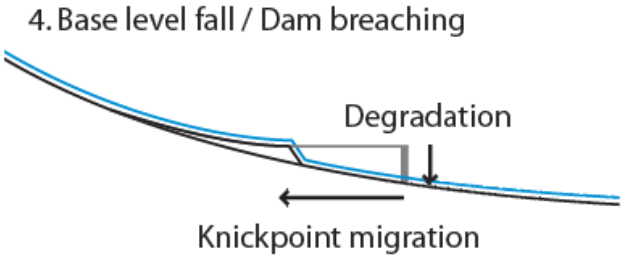
Base-Level Rise and Fall: Example of Dam Building and Dam Breaching

1919 photo



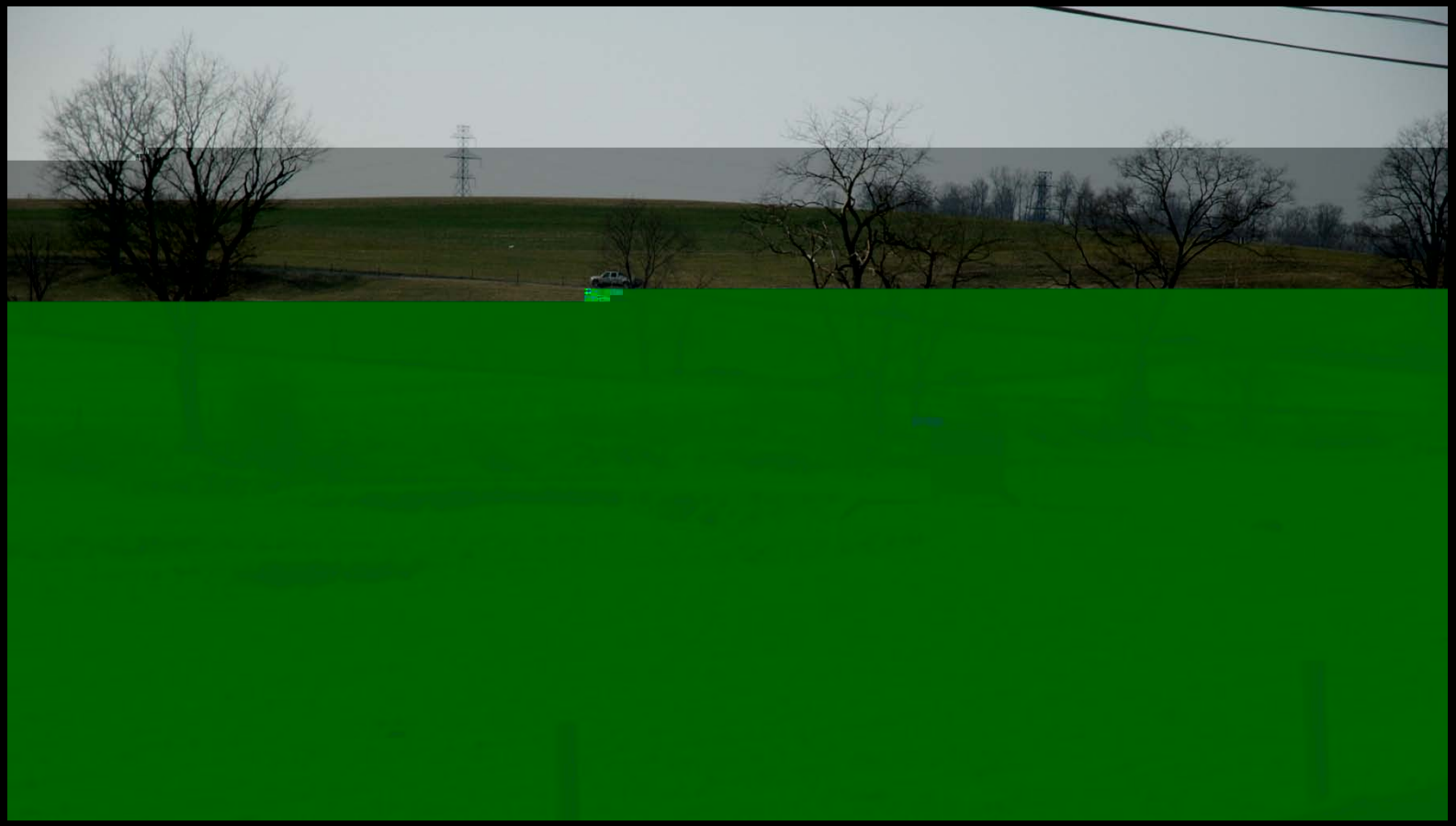






This dam is shown in the center of the lidar image in slide # 23; it breached circa 1960-1975.

When floodplains are not floodplains and the past is key to the present



Modern Analog for Pre-settlement Valley Bottom Wetlands

Valley with Historic Pond Sediment on Buried Wetland and Incised Stream